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An Analysis of Mixing Zones for Discharges from the Puget Sound Naval Shipyard and Intermediate Maintenance Facility Using CORMIX (v5.0GT)

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EXECUTIVE SUMMARY

OBJECTIVE

The United State Environmental Protection Agency Region X (US EPA), the Washington State Department of Ecology (Ecology), and the Puget Sound Naval Shipyard & Intermediate Maintenance Facility (PSNS&IMF) and Naval Base Kitsap-Bremerton (NBK-Bremerton) (for brevity, both commands are referred to, herein after as the Shipyard) are working to renew the National Pollution Discharge Elimination System (NPDES) permit for the Shipyard (US EPA 2008a,b). As part of the permit development, a mixing zone analysis is required to determine the effluent concentration that can be discharged without exceeding water quality standards. The mixing zone model CORMIX (v5.0GT, Mixzone 2009) was selected to evaluate the nature of industrial and stormwater discharges from the Shipyard. The CORMIX model was used to evaluate the mixing required to meet Washington State water quality standards (Washington State 2006) for copper (Cu) discharges from industrial and stormwater outfalls and temperature from the steam plant outfall. The standards for Cu are expressed as the dissolved fraction for acute or Constituent Maximum Concentration (CMC), of 4.8 ug/L and the chronic or Constituent Continuous Concentration (CCC) of 3.1 ug/L (Washington State 2006). Although this study calculates mixing zones for copper, it is expected that the results of this study could be extended to other metals, for example zinc.

This report presents the results of the initial mixing zone study for the purpose of obtaining the “order of magnitude” dilution factors necessary to develop achievable permit limits. The background and technical data available are reviewed, the industrial and storm water discharge systems are described, the technical approach is documented, and the preliminary results obtained for CORMIX (v5.0GT) are reported for the outfalls simulated.

RESULTS AND RECOMMENDATIONS

The CORMIX model was used to calculate mixing zones for Cu discharges from industrial outfalls for the dry docks (Outfalls (OF) 18A, 18B, and 19), representative storm water basins (PSNS015, PSNS124, and PSNS126) and temperature discharges from the steam plant (OF 21) (Table 6). The parameters used for the stormwater drainage basins (PSNS015, PSNS126, and PSNS124) were selected to be representative of the large to small drainage basins within the Shipyard.

Based on the assumptions used in the model analysis, the mixing zones for copper discharges were calculated for the CMC and CCC as follows:

- Mixing zones for OF 18A were 49.3 m for CMC (acute) and 508.2 m for CCC (chronic) exposures;
- Mixing zones for OF 18B were 18.4 m for CMC and 32.6 m for CCC;
- Mixing zones for OF 19 were 39.5 m for CMC and 63.3 m for CCC.

Because the dry dock discharges are intermittent, only discharging between 25 and 50 percent of the time, the permit limit derived from these mixing zones should be adjusted upward by a factor of two to four as allowed by the State of Washington guidance (Bailey 2008). Additionally, the permit limits derived from these mixing zones should take into account any other site-specific factors that may be incorporated into the permit (Washington State 2006), such as Water Effect Ratios and site-specific dissolved to total translators. The results from the dye study of the dry dock outfalls showed that the dye plumes reached background concentrations (i.e. concentrations that would be much lower than the CMC or CCC) within 100 m of where the plumes surfaced which indicates that the CORMIX simulations are probably more conservative than the actual discharge conditions.

The CORMIX model of the steam plant thermal discharge predicted that a mixing zone of 0.6 m would be required to meet water quality standards for temperature.

The CORMIX model was also used to simulate three stormwater basins representing large, medium, and small stormwater discharges to bracket the range of stormwater plumes expected from the Shipyard. The effluent concentrations of the stormwater were set to the 90th percentile concentration measured in the stormwater basins to calculate the mixing needed to meet water quality standards. The results showed that if the stormwater discharged at depth of 6 ft below the surface mixing zones of 1.5 m, 287.1 m, and 34.3 m would be needed to meet the CMC, for the large, medium, and small stormwater basins, respectively. If the stormwater discharges occurred at a depth of 1 ft, considerably larger mixing zones would be required.

The accuracy of the CORMIX results obtained for the storm drain discharges are highly questionable, because the CORMIX model is not designed to model surface discharges with low momentum like stormwater. Furthermore, the hypothetical CORMIX simulations of industrial and stormwater outfalls from the Shipyard neglect the effects of tidal action, intermittent discharges, the complex geometry present near the outfall discharges, over-lapping discharge plumes, and recirculation (estuarine) flow. In addition, other sources of Cu within the Inlets were not included in the discharge scenarios simulated. Therefore, the CORMIX results reported in this document are provided to inform the permit development process and do not represent actual conditions present in the receiving waters of the Inlets.

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CONTENTS

1. INTRODUCTION

The United State Environmental Protection Agency Region X (US EPA), the Washington State Department of Ecology (Ecology), and the Puget Sound Naval Shipyard & Intermediate Maintenance Facility (PSNS&IMF) and Naval Base Kitsap-Bremerton (NBK-Bremerton) (for brevity, both commands are referred to, herein after as the Shipyard) are working to renew the National Pollution Discharge Elimination System (NPDES) permit for the Shipyard (US EPA 2008a,b). Section 401 of the CWA requires a water quality certification from Ecology prior to US EPA issuance of the renewed NPDES permit. The certification conveys Ecology's determination that the discharges authorized per the NPDES permit are in accordance with Washington State Water Quality Standards (WAC 173-201A).

As part of the permit development, a mixing zone analysis is required to determine the effluent concentration that can be discharged without exceeding water quality standards. Due to the complexity of modeling discharges in dynamic estuarine systems, the project team decided[1] to apply the US EPA-supported mixing zone model CORMIX (v5.0GT, Mixzone 2009) to evaluate the nature of industrial and stormwater discharges from the Shipyard. Although the discharges from the Shipyard differ from continuous diffuser discharges usually modeled with the CORMIX framework, it was thought that the CORMIX analysis would provide information on boundary interactions, steady-state mixing behavior, and plume geometry under theoretical conditions that would inform the permit development process.

This document describes the approach used to modeling mixing zones for industrial outfall and storm drains from the Shipyard located in Bremerton, WA (Figure 1). The background and technical data available are reviewed, the industrial and storm water discharge systems are described, the technical approach is presented, and the preliminary results obtained for CORMIX (v5.0GT) simulations are reported for the industrial outfalls and representative storm drains.

The CORMIX model was used to evaluate the mixing required to meet Washington State water quality standards (Washington State 2006) for copper (Cu). The standards for Cu are expressed as the dissolved fraction for acute or Constituent Maximum Concentration (CMC), of 4.8 ug/L as "the 1-hour average concentration not to be exceeded more than once every three years on the average," and the chronic or Constituent Continuous Concentration (CCC) of 3.1 ug/L, as "the 4-day average concentration not to be exceeded more than once every three years on the average" (Washington State 2006).

[1] Meeting of Jan. 20, 2009 with US EPA, US Navy, and Ecology in Seattle, WA.

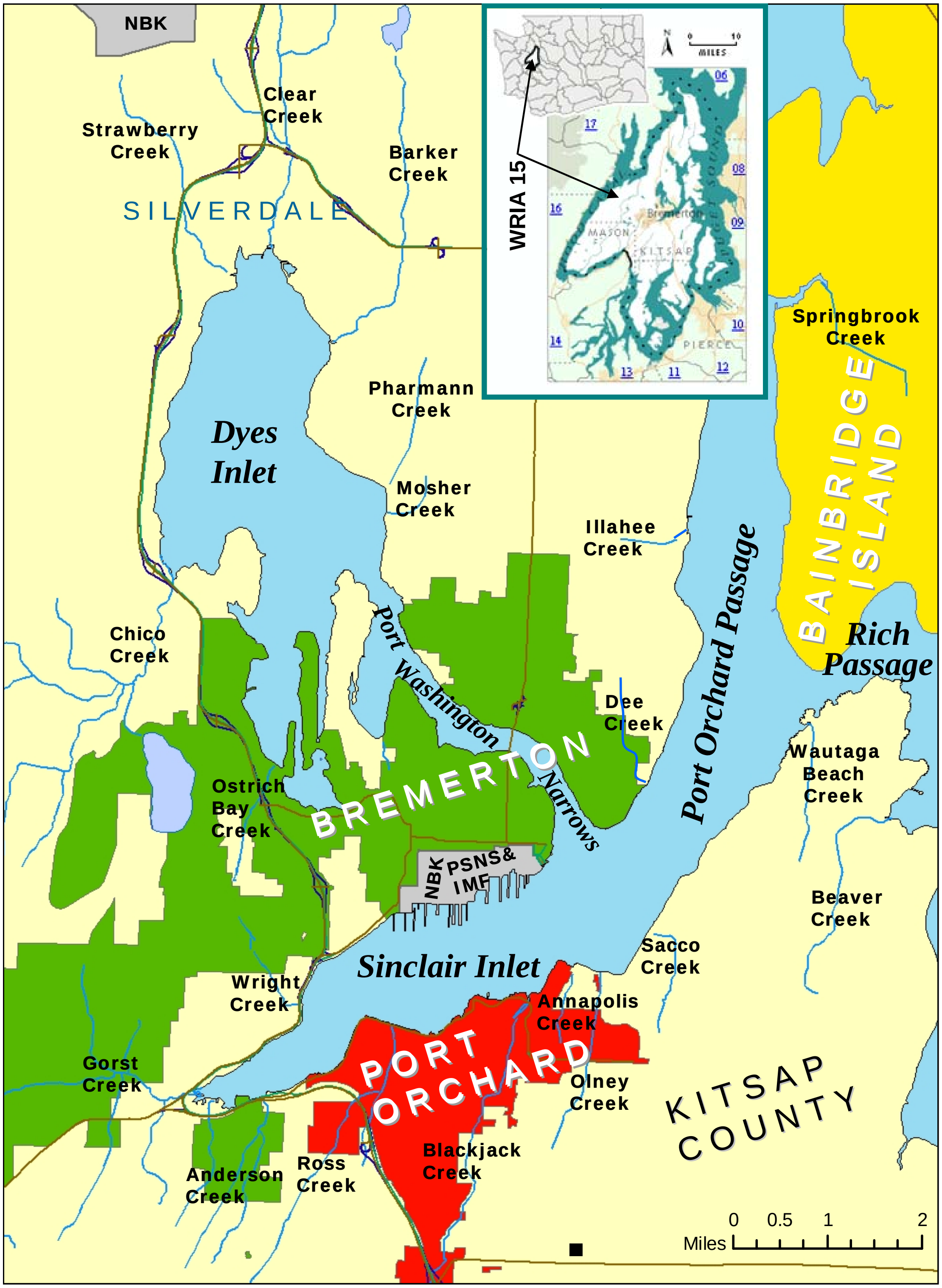


Figure 1. The location of PSNS&IMF and NBK on Sinclair Inlet in Bremerton, WA.

2. SUPPORTING INFORMATION

2.1 BACKGROUND

The Puget Sound Navy Yard was established in 1891 and the town of Bremerton was founded in 1901. Rapid development in Bremerton and a boom in the population of Kitsap County followed major expansions at the Shipyard during World War I and World War II. At the height of World War II the population of Bremerton peaked at more than 80,000 people and industrial operations poured out goods for the war effort. Following the end of World War II, work at the Shipyard was reduced, but the Shipyard's workload remained high throughout the cold war and into the 1980s and 1990s. In order to improve fleet readiness by increasing the Navy's ability to complete high priority, real-time ship maintenance requirements in a cost effective manner, Puget Sound Naval Shipyard and the Naval Intermediate Maintenance Facility, Pacific Northwest (located at Bangor, Bremerton, and Everett, WA), were consolidated in May 2003 into one maintenance activity - creating PSNS&IMF. Bordered on the south by Sinclair Inlet, on the west by Naval Base Kitsap Homeport, and on the north and east perimeters by the City of Bremerton, the Shipyard is the Pacific Northwest's largest Naval shore facility and one of Washington State's largest industrial installations (PSNS&IMF 2008).

In 2000, a collaborative partnership formed through an ENVivronment inVEStment (ENVVEST) partnership among PSNS&IMF, Ecology, U.S. EPA, and local stakeholders began conducting a comprehensive water quality improvement project for the watersheds of Sinclair and Dyes Inlets (FR 2000). By addressing environmental concerns at the proper ecological scale, Project ENVVEST has made major contributions in addressing environmental concerns in the Inlets by providing data to determine the total daily loading of priority constituents and developing a more efficient and effective means of protecting the environment (Ecology 2008). Project ENVVEST is part of EPA's eXcellence and Leadership Program which was developed to give communities, states and local agencies, federal facilities, and industry the opportunity to propose cleaner, cheaper, and smarter ways of protecting the environment (US EPA 2000a). Under the Clean Water Act (CWA), Total Maximum Daily Loads (TMDLs) are developed to determine the amount of a given constituent that can be discharged to a waterbody without causing the waterbody to exceed water quality standards and TMDLs can aide in the implementation of Water Quality Improvement Projects by identifying the critical conditions and sources of contaminants entering the waterbody (US EPA 2009). The goal of Project ENVVEST is to create an alternative model for the development and implementation of environmental regulations and provide the technical data and information needed to implement TMDLs for the Sinclair/Dyes Inlet Watershed adjacent to the Shipyard (US Navy, US EPA, Ecology 2000, US EPA 2000b) and achieve real improvements in environmental quality with less cost.

2.2 INDUSTRIAL OUTFALLS

The Shipyard has four major industrial outfalls (OF) including the outfalls for Dry Docks 1, 2, 3, 4, and 5 (OF 18A and 18B), the outfall for Dry Dock 6 (OF 19), and the stream plant outfall (OF21) (Figure 2).

Outfall 18A and 18B discharge from Dry Docks 1 through 5. The water is pumped to OF 18A and 18B through pumpwell #5 (located at dry dock 5) or pumpwell #4 (located at dry dock 4). The pumpwells operate in lead-lag mode, with the lead pumpwell being alternated monthly. Both outfalls discharge just west of dry dock 4 (Figure 3). Outfalls 18A and 18B are periodic discharges with the pumps cycling every 4 hours (1 hr on, 3 hr off). Outfall 18A discharges below mean lower low water (MLLW) at a discharge height of 19 f (5.79 m) above the bottom while Outfall 18B discharges above MLLW at a discharge height of 21.4 ft (6.52 m) above the bottom.

Water from Dry Dock 6 is pumped from pumpwell 6 to OF 19 which discharges on the east side of the end of pier 9 (Figure 4). Outfall 19 is a periodic discharge, with the pump cycling every 15 to 30 min (on for 7.5 min). Outfall 19 discharges below MLLW at a discharge height of 23.9 ft (7.28 m) above the bottom.

Outfall 21 discharges treated water from the stream plant. The wastewater consists of effluent from regeneration of the plant’s ion exchangers along with steam condensate and boiler blow-down water. The treated water is discharged through a 0.1 m pipe with a 12.1 m long diffuser starting 279.8 m from the shore at a depth of 10.67 m (Figure 2).

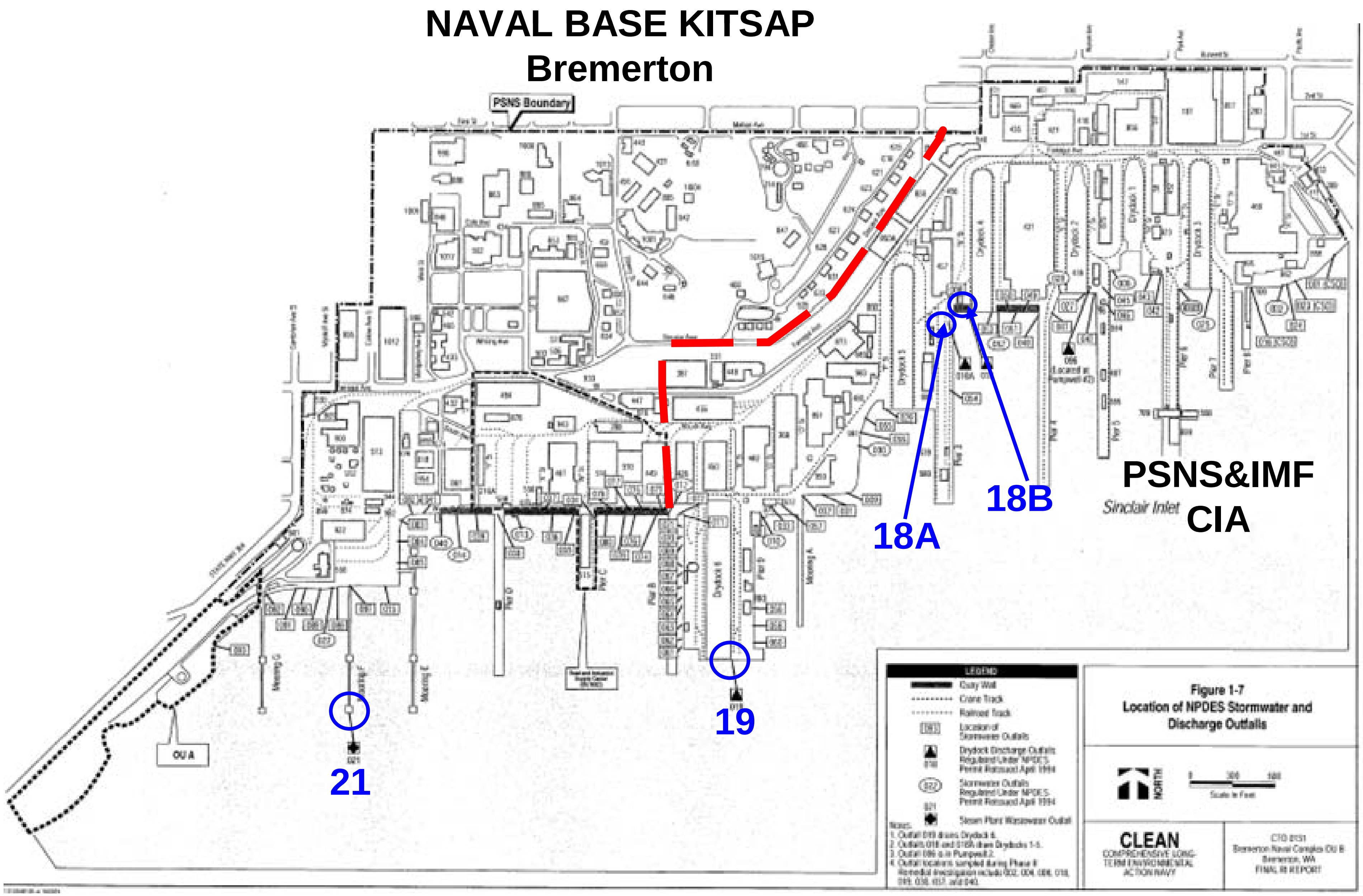
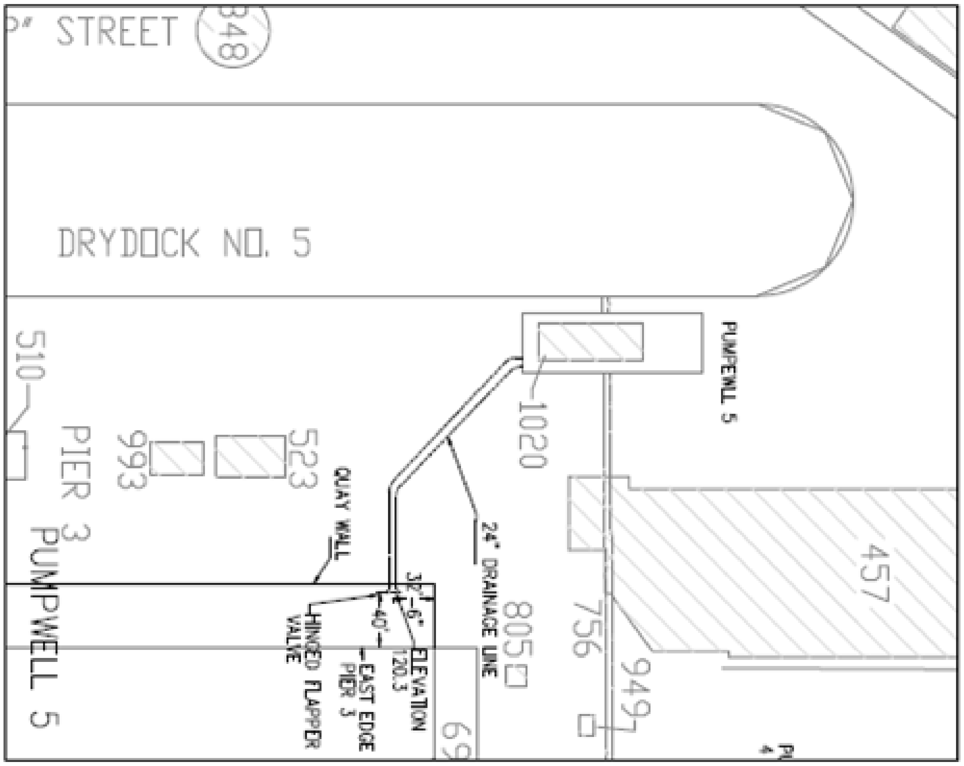


Figure 2. Diagram showing the boundary between NBK and PSNS&IMF (red line) and location of industrial outfalls (blue circles) and storm drains located in the Shipyard.

18A



18B

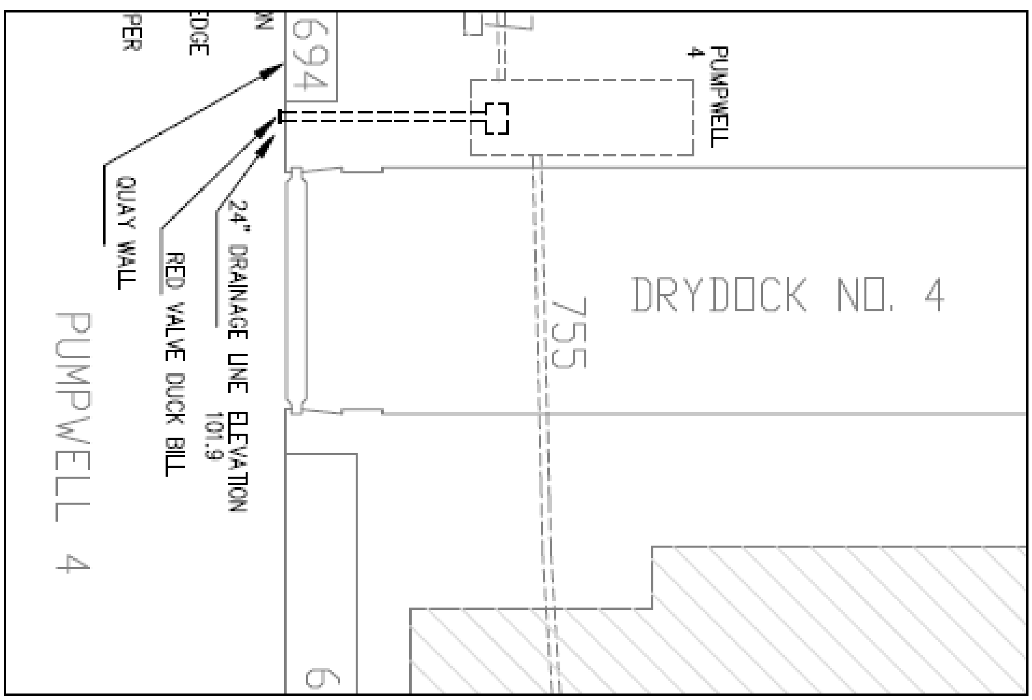


Figure 3. Diagram of outfalls 18A and 18B.

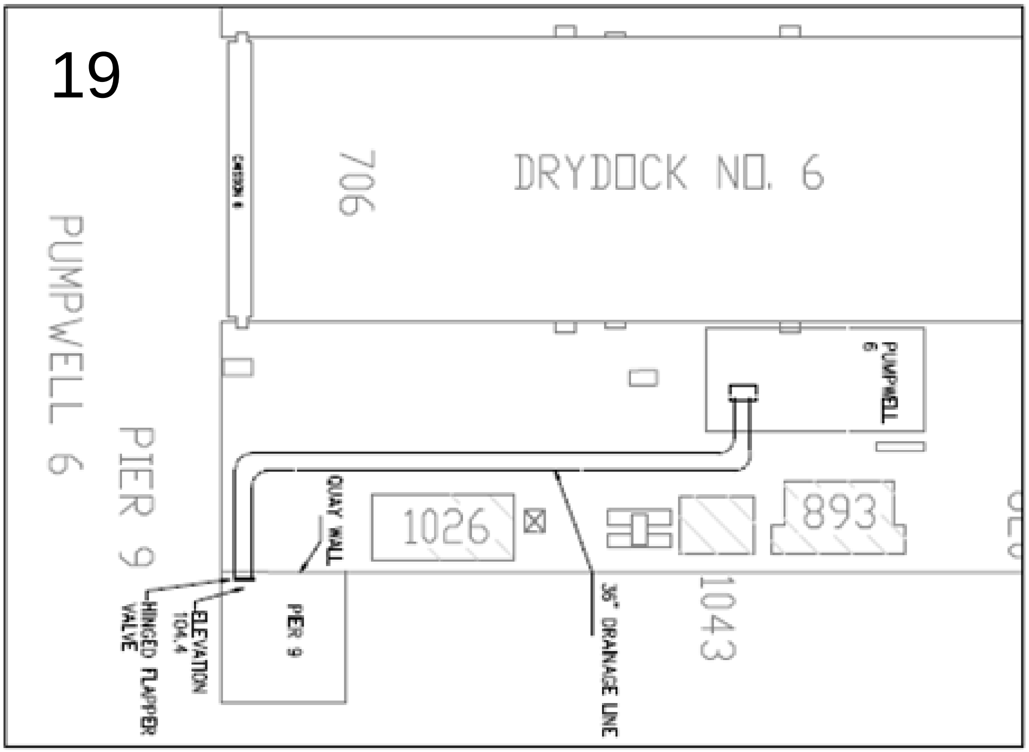


Figure 4. Diagram of outfall 19.

2.3 STORM DRAINS

Storm drains are located all along the waterfront and on the piers (Figure 1). As part of Project ENVVEST, thirteen storm water drainage basins within the watershed, including 3 basins within the Shipyard, were monitored for flow and sampled during storm events (Johnston et al. 2005). The storm water outfalls selected for flow monitoring were determined by a technical evaluation of 35 storm water outfalls (including streams and other urbanized natural drainage areas) located within the City of Bremerton, City of Port Orchard, City of Bainbridge Island, Kitsap County, and the Shipyard (TEC 2003a, b, c). This work resulted in a calibrated and verified Hydrological Simulation Program Fortran (HSPF) for drainage basins within the watershed including the Shipyard (Figure 1, Skahill and LaHatte 2007) and estimates of stream and storm event runoff quality as a function of upstream land use and cover and storm intensity (Brandenberger et al. 2007a, b, Cullinan et al. 2007). The ENVVEST Studies also provided data that was used to develop a contaminant mass balance for heavy metals (Cu, Pb, Zn, and Hg), PAHs, and PCBs, and loadings of nutrients (Brandenberger et al. 2008).

The stormwater system at the Shipyard is very complex. The stormwater system drains runoff from both the Naval Station and Controlled Industrial Area (CIA) areas of the Shipyard (Figure 2). The predominant land cover types within the Shipyard are roof tops, paved areas (roads, parking areas, sidewalks, and concrete working areas) and piers (Figure 6). Of the 156 storm drains, many serve small drainage areas and there are more than 1,000 catch basins or track drains on piers that drain directly into Sinclair Inlet. Additionally, the extensive rail system within the Shipyard provides a pathway for stormwater to seep through the subsurface. Depending on the rate of flow and whether the track drains become clogged, this runoff will ultimately discharge directly into Sinclair Inlet (Jabloner et al. 2008).

As described in the AKART study the "… stormwater system is composed primarily of clay pipe with concrete, PVC, steel, and cement-asbestos pipe generally making up the balance of the piping. The depth of the stormwater system ranges from 1 foot to 20 feet below ground surface. Within the industrial area, stormwater is collected from building roofs by rain gutters and roof drains. The roof drains discharge into storm drain piping or into catch basins located around the buildings. The ground surfaces around the buildings are impervious surfaces made of asphalt or concrete or concrete base with asphalt over it. Within the industrial area there are no unpaved areas therefore infiltration of stormwater into site soil is minimal. On the piers and other surfaces located directly over the water there are drain holes in the deck which deposit the rainwater directly into Sinclair Inlet" (Jabloner et al. 2008).

Many of the major storm drains discharge to Sinclair Inlet below MLLW while most of the smaller stormwater basin drain by gravity flow above MLLW. Because the Shipyard is only a few feet above high tide, most of the stormwater piping is tidally influenced further complicating the mixing and runoff processes. "This increases the complexity of taking stormwater samples and makes it difficult to use passive stormwater treatment systems. This is especially true for the drainage areas closest to the waterfront, which are also the most industrialized areas" (Jabloner et al. 2008).

For the modeling exercise, three representative storm basins were modeled: a large basin (DSN167) draining at PSNS015, a medium-size basin (DSN177 which includes City of Bremerton basins DSN220 and DSN218) draining at PSNS0126, and a small basin (DSN176) draining at PSNS124 (Figure 6).

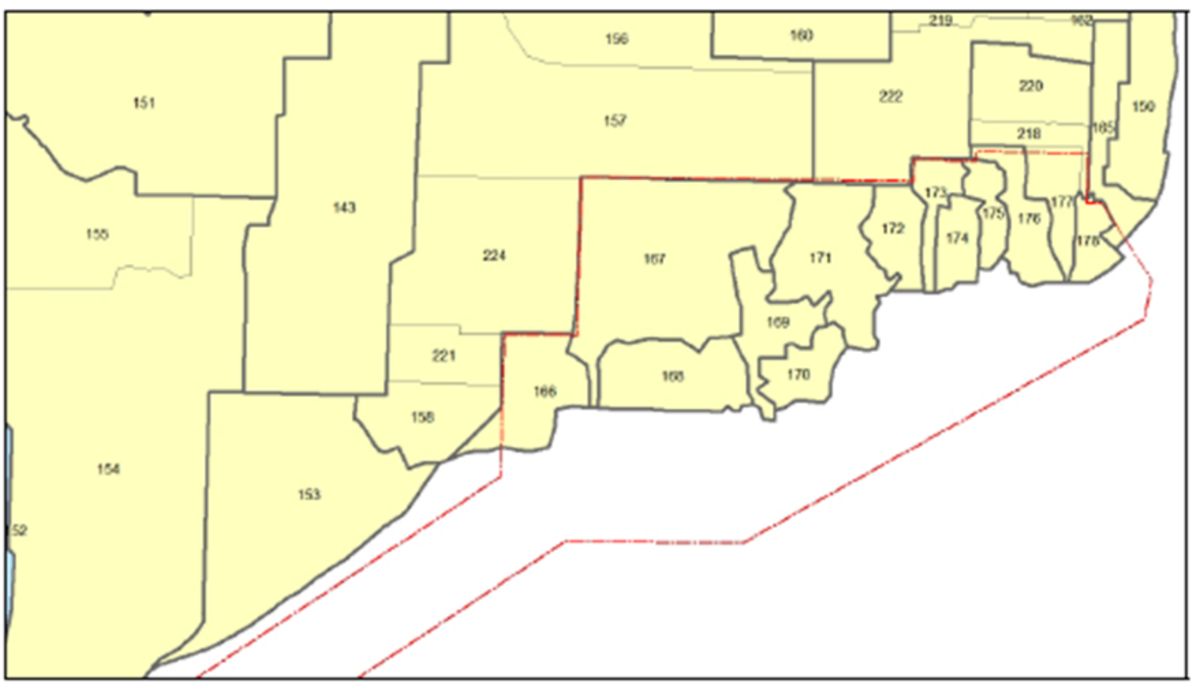


Figure 5. Storm water basins within the Shipyard boundary (red line) containing PSNS&IMF and Naval Station Kitsap – Bremerton with flows modeled by the HSPF model for Sinclair and Dyes Inlets (Skahill and LaHatte 2007).

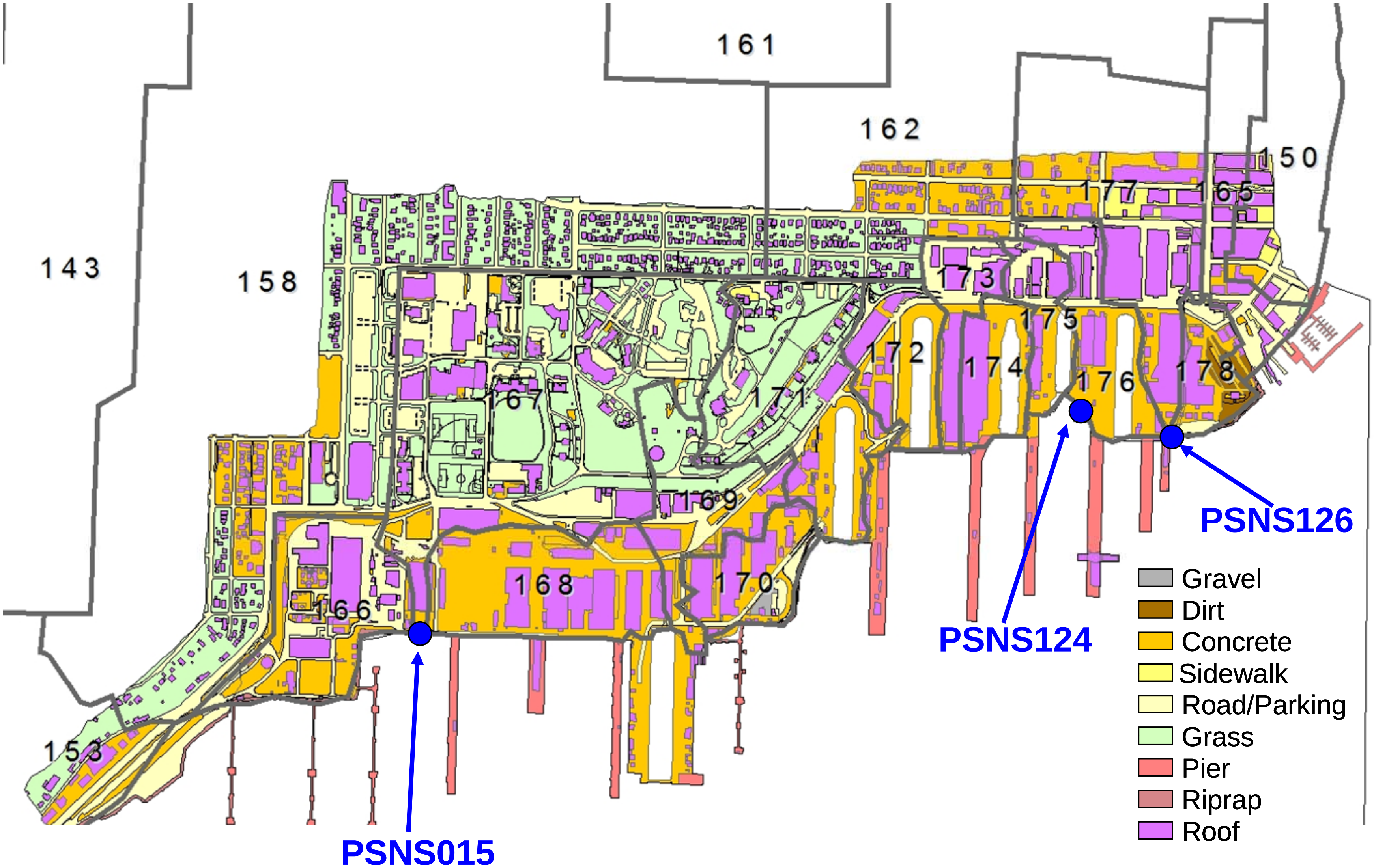


Figure 6. The predominate land cover types and stormwater basins within the Shipyard and the stormwater drains modeled with CORMIX.

2.4 DATA SUMMARY

2.4.1 Ambient Data

Concentrations of total and dissolved Cu were measured during the ECOS Survey conducted between September 1997 and July 1998 (Katz et al. 2004) and between March 2002 and September 2005 during the ENVVEST Studies (Brandenberger et al. 2006, 2007a,b) were used to characterize the ambient dissolved and total copper present in Sinclair Inlet. The data sets from the above studies were subset to select only samples collected within Sinclair Inlet which included nearshore and marine stations sampled during wet and dry base flow conditions as well as during storm events (Katz et al. 2004, Brandenberger et al. 2007a,b). The dissolved Cu concentration ranged from 0.4 to 2.6 ug/L for both data sets. The 95th percentile upper confidence level of the mean (95th UCL) was calculated using the minimum-variance unbiased estimator (MVUE) of the log-normal mean and jackknife derived UCLs calculated for each of the data sets (see Appendix). The dissolved Cu concentrations measured during the ENVVEST studies (0.95 ug/L 50th percentile) were slightly higher than the concentrations measured during the ECOS survey (0.7 ug/L 50th percentile), probably because the ENVVEST data included samples taken in nearshore areas immediately following storm events (Table 1, Figure 7)

The 95th UCL obtained from ECOS survey data of 0.818 ug/L was selected as the background dissolved Cu concentration for the modeling runs. In accordance with the CORMIX modeling procedures (Mixzone 2009), the effluent concentration and the Washington State water quality standards for dissolved Cu for acute (4.8 ug/L) and chronic (3.1 ug/L) exposures were adjusted by subtracting the background concentration for the model runs.

Table 1 Summary of the dissolved and total copper concentrations measure in Sinclair Inlet during the ECOS Surveys (1997-98), ENVVEST Studies (2002-2005), and for all data combined.

	Copper ug/L					
	All Data 1997-2005		ECOS Data 1997-98		ENVVEST DATA	
	Dissolved	Total	Dissolved	Total	Dissolved	Total
n	175	93	106	24	69	69
Geomean	0.804	1.176	0.731	1.022	0.931	1.235
Mean	0.875	1.317	0.773	1.108	1.033	1.390
95th UCL	0.919	1.426	0.818	1.286	1.138	1.535
Min	0.441	0.577	0.441	0.577	0.447	0.591
Max	2.570	3.880	2.210	2.575	2.570	3.880
Percentiles						
10%	0.500	0.681	0.497	0.665	0.519	0.697
25%	0.582	0.823	0.564	0.808	0.640	0.878
50%	0.759	1.130	0.713	0.959	0.945	1.210
75%	1.015	1.510	0.910	1.305	1.210	1.570
90%	1.322	2.286	1.189	2.459	1.862	2.340

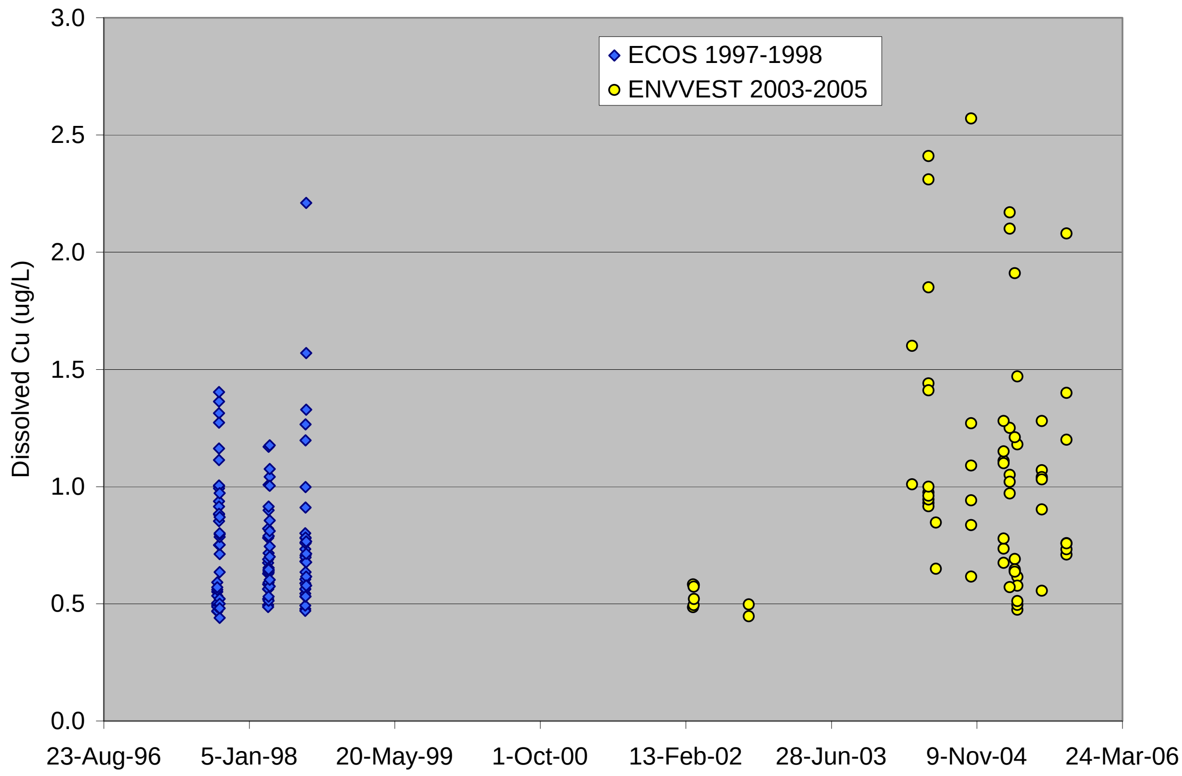


Figure 7. Concentrations of dissolved Cu measured in samples collected in Sinclair Inlet during the ECOS survey and ENVVEST study.

2.4.2 Current data

A bottom-mounted Acoustic Doppler Current Profiler (ADCP) was moored within the Shipyard near outfalls 18A and 18B from November 11 to December 6, 2005 (Figure 8, Johnston and Albertson 2005). Briefly, the ADCP resolves current velocities by measuring the Doppler shift of the acoustic backscatter generated by particles (phytoplankton, zooplankton, and particulates) suspended and traveling in the water column (RDI 1996). Data provided by the ADCP includes velocities (speed and direction), echo intensity, correlation of data quality, and percent good data – based on predefined thresholds– for each bin or cell depth measured in the water column (RDI 1996). The ADCP mooring provided a continuous data set to evaluate tidal currents throughout the water column over the 14-day spring-neap tidal cycle in an area within the Shipyard with lower current velocities and restricted mixing.

The data obtained from the current meter deployment are summarized in Figure 9 and Table 2.

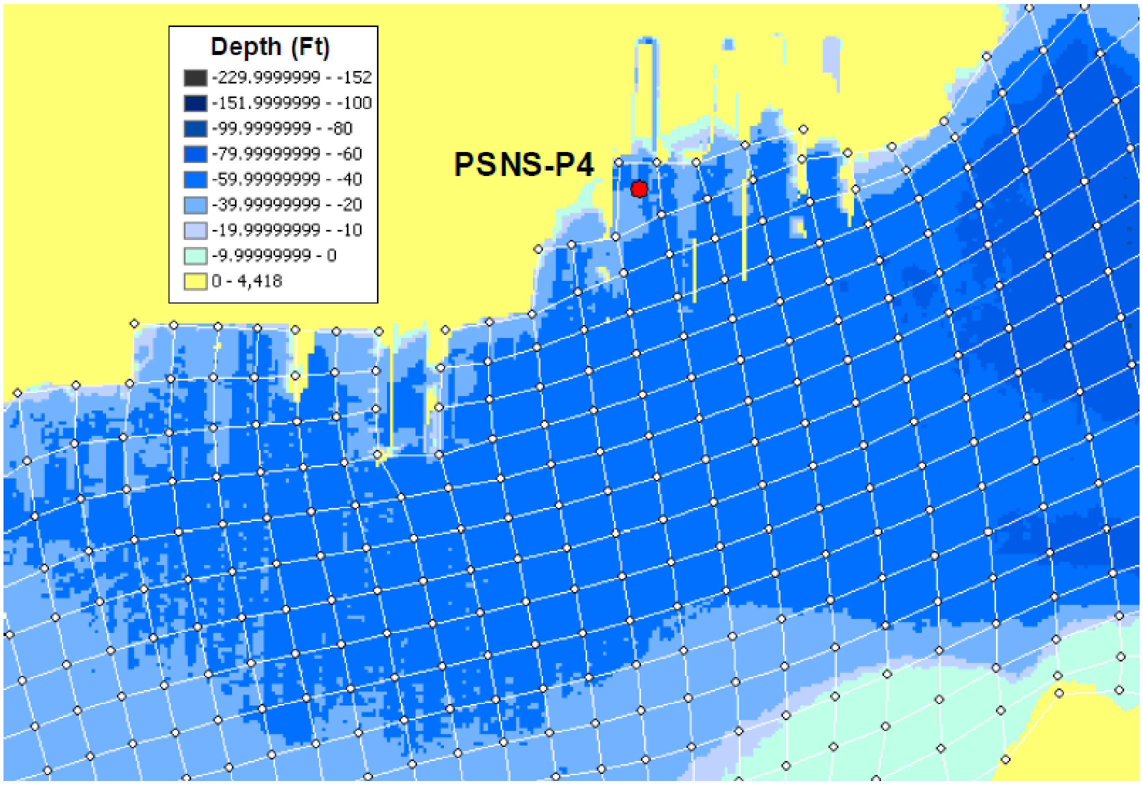
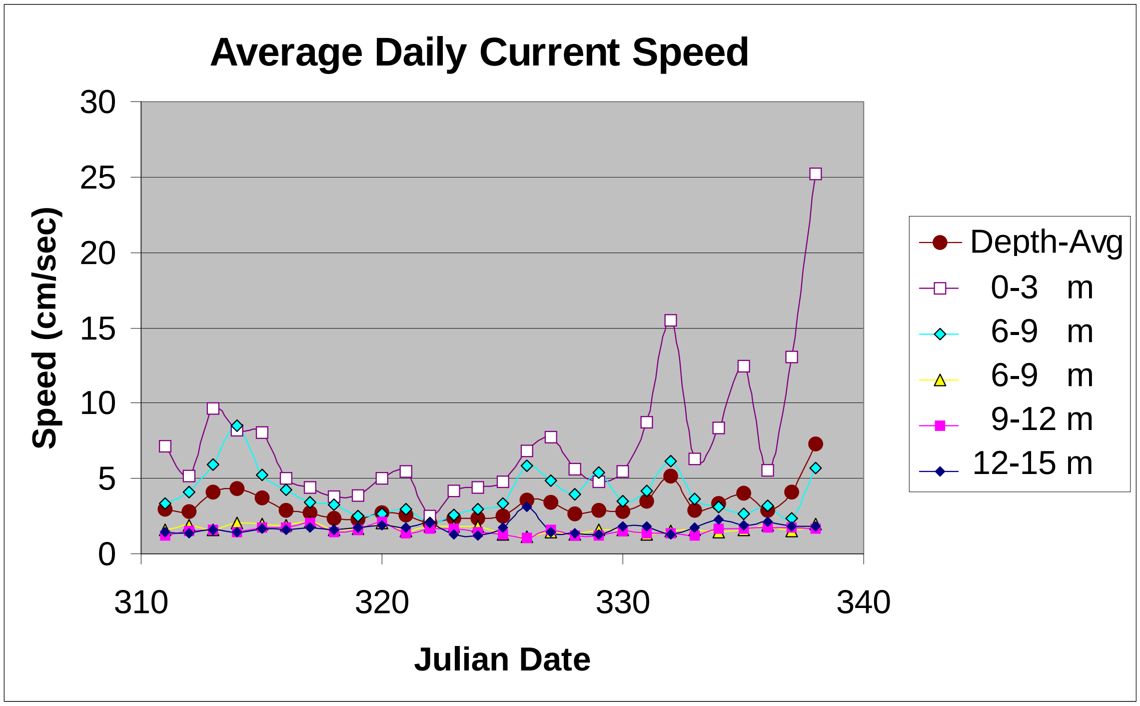


Figure 8. Location of the current meter station in Sinclair Inlet, within the Shipyard. The ADCP was deployed on the bottom from 1405 Nov. 11, 2005 to 2053 Dec. 6, 2005. The CH3D (91x94) numerical grid is also shown. Bathymetry data from Finlayson (2005).



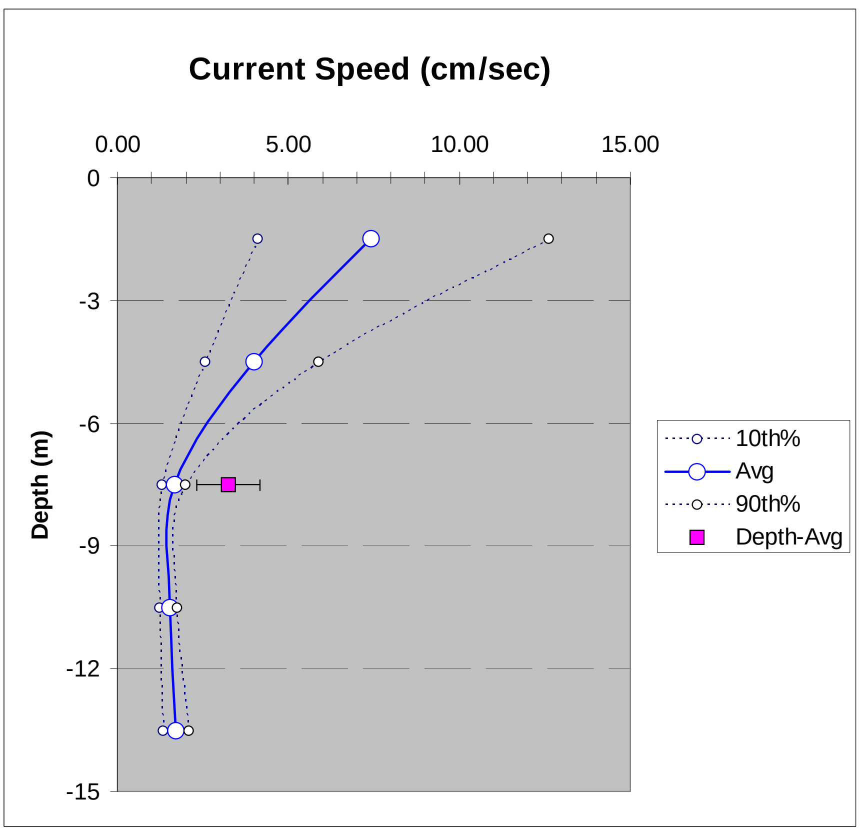


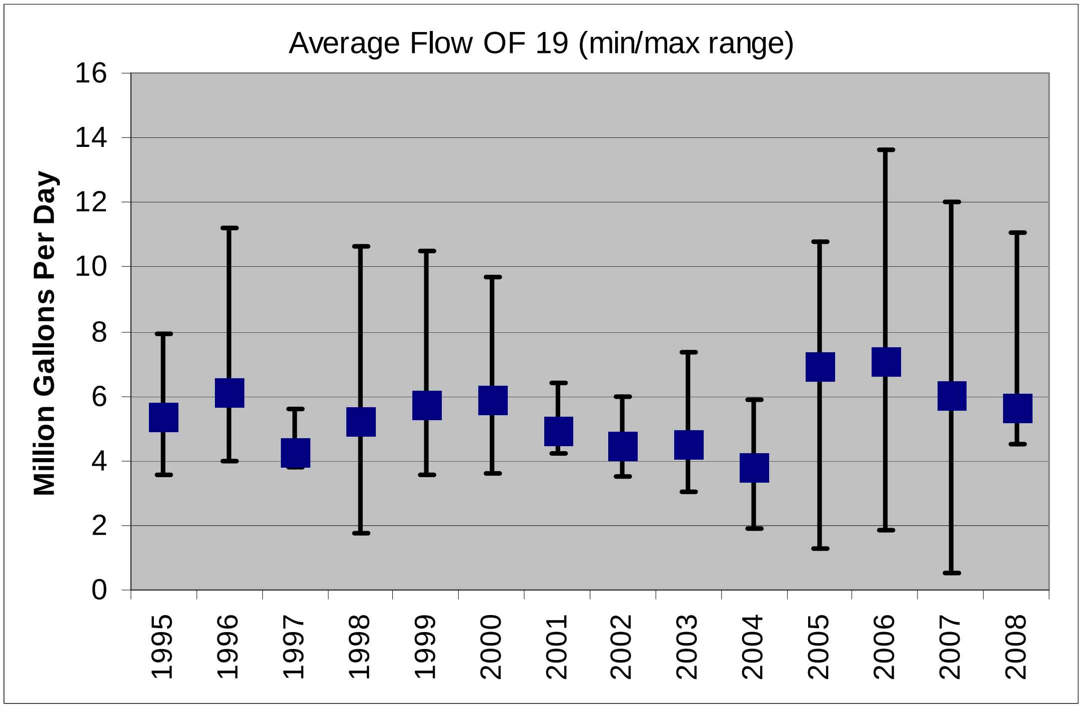
Figure 9. The average daily current speed (cm/sec) for each depth bin in distance from surface (top panel) and average current depth profile and depth averaged current (bottom panel) obtained from the current meter deployed in the Shipyard.

Table 2. Summary of current data for each day of deployment and statistical summary for the complete deployment period.

	Current Speed cm/s					
	Depth from Bottom (m)					
Julian Day	**0-3**	**3-6**	**6-9**	**9-12**	**12-15**	**depth-Avg**
311	1.46	1.20	1.61	3.37	7.14	2.96
312	1.34	1.50	1.90	4.09	5.15	2.79
313	1.58	1.62	1.63	5.89	9.65	4.08
314	1.43	1.44	2.03	8.48	8.21	4.32
315	1.68	1.72	1.96	5.25	8.04	3.73
316	1.62	1.73	1.90	4.25	5.03	2.90
317	1.77	2.07	2.13	3.45	4.38	2.76
318	1.59	1.44	1.62	3.24	3.83	2.34
319	1.76	1.63	1.70	2.48	3.86	2.28
320	1.91	2.09	2.05	2.65	4.98	2.74
321	1.78	1.35	1.48	2.96	5.45	2.60
322	2.06	1.70	1.83	2.05	2.52	2.03
323	1.33	1.68	1.79	2.59	4.20	2.32
324	1.21	1.47	1.81	2.97	4.43	2.38
325	1.72	1.29	1.26	3.35	4.81	2.49
326	3.10	1.07	1.14	5.85	6.83	3.60
327	1.46	1.60	1.41	4.86	7.75	3.42
328	1.33	1.22	1.30	3.95	5.59	2.68
329	1.28	1.23	1.62	5.38	4.79	2.86
330	1.85	1.52	1.59	3.52	5.49	2.79
331	1.80	1.40	1.26	4.14	8.73	3.47
332	1.32	1.35	1.54	6.13	15.46	5.16
333	1.71	1.22	1.61	3.63	6.27	2.89
334	2.28	1.69	1.42	3.12	8.36	3.37
335	1.91	1.68	1.63	2.64	12.45	4.06
336	2.14	1.75	1.90	3.20	5.52	2.90
337	1.85	1.72	1.50	2.33	13.04	4.09
338	1.79	1.65	1.94	5.71	25.22	7.26
average	1.72	1.54	1.66	3.98	7.40	3.26
10th percentile	1.33	1.22	1.29	2.56	4.10	2.33
50th percentile	1.72	1.56	1.62	3.49	5.55	2.89
90th percentile	2.08	1.73	1.98	5.86	12.62	4.16

2.4.3 Dry Dock Discharge Data

Since 1994, the flow and concentration of Cu in the discharges from OF 19, 18A, and 18B have been monitored as part of the Shipyard's NPDES permit. The flow rate for OF 19 ranges between 4 – 13 MDG and about 1.5 – 7 MGD for OF 18A and 18B (Figure 10). The concentration of Cu measured in the dry dock outfalls was highly variable during the 1990s but decreased significantly since the Process Water Collection System (PWCS) was brought online in 2000. Briefly, the PWCS monitors the dry dock discharges and is capable of diverting discharges to the sanitary sewer if turbidity levels exceed pre-selected levels or other operational parameters (e.g. dry dock wash down) indicate of potentially high levels of contaminants in the waste stream.



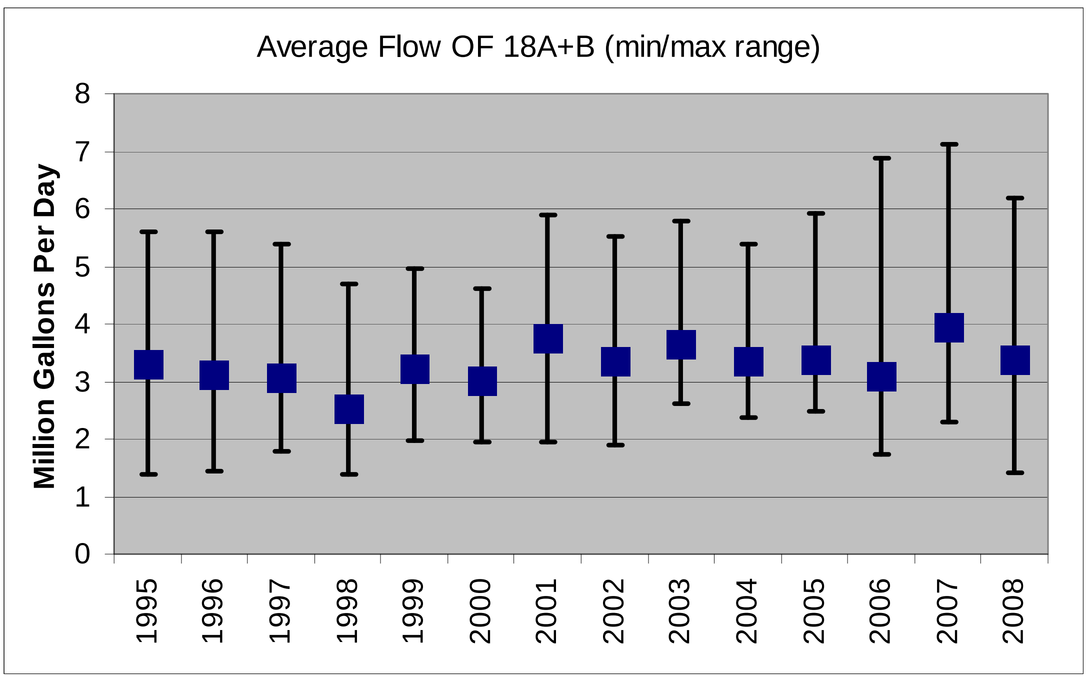


Figure 10. The average and range of flow rate measured for dry dock discharges from 1995 to 2008.

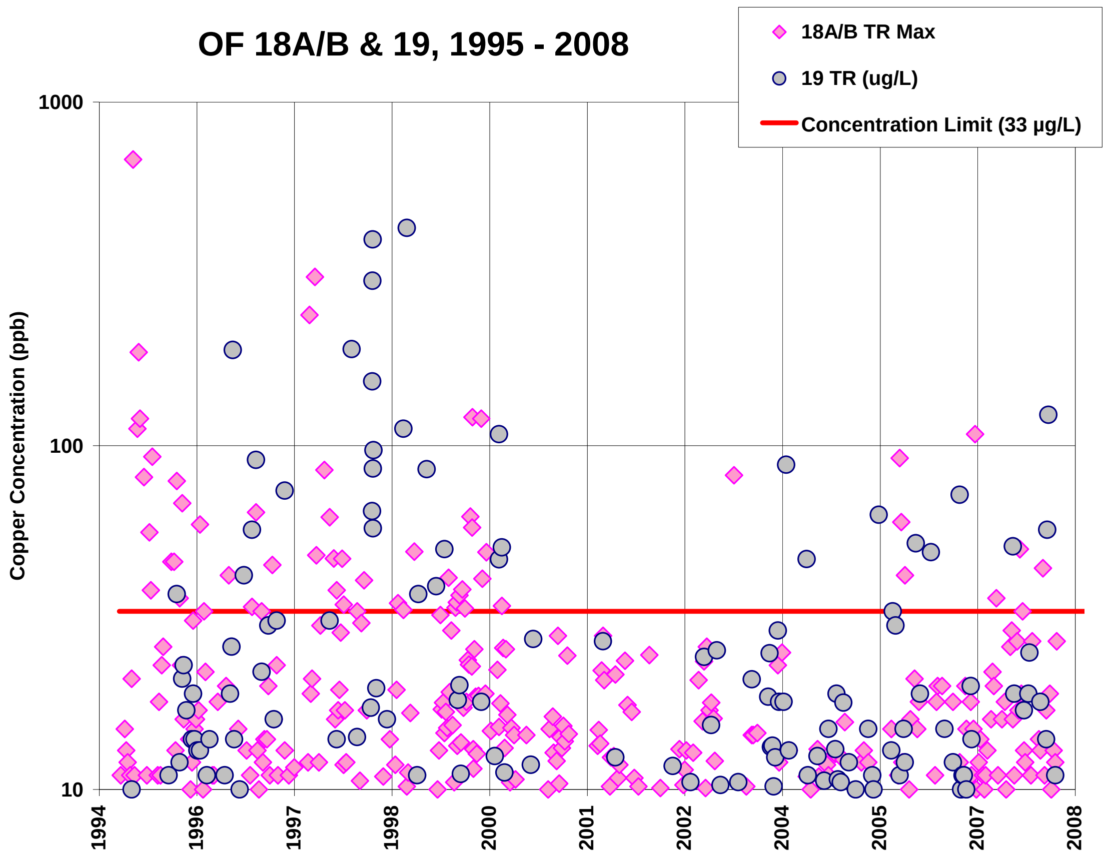
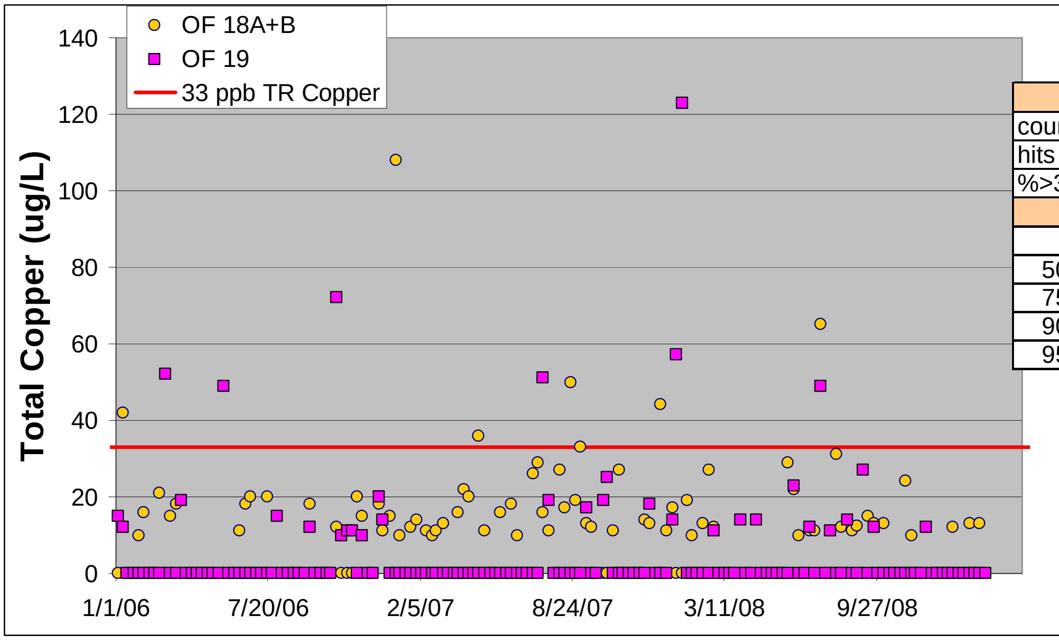


Figure 11. The concentration of total recoverable (TR) Cu measured in effluents from OF 19 and 18A/18B from 1995 to 2008.

Currently, additional BMPs are being implemented for the PWCS and dry dock operations to correct exceedances and improve the performance of the PWCS to achieve the current discharge limit of Total Recoverable (TR) 33 ppb of Cu (Figure 11). Furthermore, it is anticipated that the implementation of additional BMPs identified in the AKART study (Jabloner 2008) would further improve compliance with the 33 ppb limit (B. Beckwith, PSNS&IMF, personal commutation).

The most recent dry dock outfall data were evaluated to determine the relative frequency of exceedances and variability in the monitoring data (Figure 12). The analysis shows that since January 2006 more than 95% of the monitoring samples were below the discharge limit of 33 ppb and that 90% of the samples were below 21.7 ppb at OF 18A and 18B, and below 15.0 ppb at OF 19. Therefore, the effluent concentration (C_E) of the outfalls for the CORMIX simulations was set to the discharge limit (33 ppb) after adjusting for the dissolved:total Cu fraction (T = 0.83) and background concentration (B = 0.818 ppb):

$$C_E = (33)(T) - B = 26.572 \qquad \text{EQU [1]}$$



	OF18A+B	OF19
count	164	165
hits	6	7
%>33	3.7%	4.2%
Percentiles		
	TR Cu (ug/L)	
50%	0.0	0.0
75%	14.0	0.0
90%	21.7	15.0
95%	29.0	24.6

Figure 12. The results from Discharge Monitoring Report showing the most recent monitoring data collected from the dry dock outfalls.

2.4.4 Steam Plant

The outfall for Building 912 discharges treated water from the Shipyard's steam plant. The wastewater consists of effluent from regeneration of the plant's ion exchangers along with steam condensate and boiler blow-down water. The outfall consists of a 40 foot, 8 inch diameter pipe with five, 3 inch diameter holes discharging horizontally, spaced at 10 feet, on alternating sides. The diffuser is at right angles to the shore, starting at 918 feet from shore, at a depth of 35 feet (Figure 2). The discharge pumps run intermittently and have varying discharge rates, 300 gpm is the upper end value with the majority of the flow less than 175 gpm. The maximum currently permitted discharge temperature is 32 deg C.

2.4.5 Stormwater Data

The mixing zone analysis for stormwater consists of modeling representative stormwater runoff from 3 selected basins: a large basin (DSN167) draining at PSNS015, a medium-size basin (DSN177 which includes City of Bremerton basins DSN220 and DSN218) draining at PSNS0126, and a small basin (DSN176) draining at PSNS124 (Figure 6). Each of the stormwater basins discharge into a single outfall for the purposes of estimating the amount of mixing that will occur in receiving waters. For each outfall, the model was run with two different discharge depths (6 feet and 1 foot from the surface). It was assumed that this approach would bracket the mixing that would occur from all the stormwater drains. This is also more practical, as it would be very difficult to obtain flow and concentration data for each of the 156 storm drains (Figure 2).

In order to model mixing from stormwater discharges an accurate estimate of flow from the stormwater basins is needed. During the ENVVEST studies, flow data was successfully collected from 3-representative basins within the Shipyard at monitoring stations PSNS015, PSNS124, and

PSNS126 (basin ids 167, 176, and 177[2], see Figure 5). This and other data from the watershed were used to calibrate and verify the Hydraulic Simulation Program Fortran (HSPF) watershed model which was capable of simulating watershed-scale runoff based on rainfall and local meteorological conditions (Skahill and LaHatte 2006, 2007). The watershed model was used to simulate flows to estimate fecal coliform (FC) loading as part of the Total Maximum Daily Loading (TMDL) modeling study for the Inlets (Johnston et al. 2008).

For the mixing zone analysis local rainfall data from Oct. 1, 2004 to Sep. 30, 2005 (Water Year 2005) were used to simulate the daily flows from each basin. The total modeled flow (m^3/yr), the median, 25th and 99.98th percentile of the hourly flow rate (average hourly flow in cubic feet per second (CFS)) and were calculated for each basin (Table 4). Based on the hydrologic processes simulated by HSPF, the simulation provides a relatively accurate estimate of stormwater flows from the Shipyard. For the model input, the upper bounds of the hourly flow rate of 1.5, 0.8, and 0.6 were selected for PSNS015, PSNS126, and PSNS124, respectively (Figure 13).

The concentration of Total Cu in each of the stormwater basins was estimated using data developed during the ENVVEST studies (Table 3). The dissolved Cu concentration used in the CORMIX simulations was the 90th percentile estimated from the five sampling events, adjusted for the dissolved:total Cu fraction (0.83) and background concentration (0.818 ppb) (EQU[1]). The model flows obtained from the ENVVEST HSPF model were also used to estimate the total annual loading of copper from Shipyard storm drains (Table 4). These estimates are based on copper data collected during the ENVVEST study and NPDES stormwater monitoring conducted in 1994-1996 (Figure 14, Figure 15, Figure 16).

Table 3. Summary of Cu data for Shipyard stormwater drains sampled during the ENVVEST Study and the input concentration used in the CORMIX simulations.

		Total Cu (ppb)		
Date	Rainfall (in)	PSNS015	PSNS126	PSNS124
4/19/2004	0.26	21.100	40.900	147.167
5/26/2004	0.46	42.400	132.650	138.167
10/18/2004	0.5	27.300	22.900	191.000
2/28/2005	0.37	19.900	29.200	79.200
3/19/2005	0.84	12.800	26.900	55.300
Average		24.700	50.510	122.167
90th Percentile		36.360	95.950	173.467
Translator (T) dissolved:total		0.830	0.830	0.830
Background (B)		0.818	0.818	0.818
		Dissolved Cu (ppb)		
CORMIX Input Conc.		29.361	78.821	143.159

[2] Previously, basin 177 received runoff from the City of Bremerton as well as the shipyard. As part of the Bremerton tunnel project during the winter of 2008-2007, the runoff from Bremerton was diverted to the City's outfall.

Table 4. The total modeled flow (m^3/yr), the median, 25th and 99.98th percentile of the daily flow rate (average hourly flow in cubic feet per second (CFS)) Estimated annual loads of copper discharged from Shipyard stormwater basins based on ENVVEST data.

						Average Hourly Flow (CFS)			Cu Concentration ug/L (Wet Season)				Copper Loading Kg/yr		
DSN No.	**Basin Type**	**Basin Description/Location**	**WQ ID**	**Watershed Area (acres)**	**Yearly Flow m^3**	**Yearly Median**	**25th Percentile**	**99.98th Percentile**	**Median**	**25th**	**75th**	**n***	**Median**	**25th**	**75th**
166	Stormwater	PSNS008 Inactive Ships	PSNS008	29.8	1.61E+04	0.0002	0.0002	1.3144	44.2	44.2	44.2	1	0.71	0.71	0.71
167	Stormwater	PSNS015 McDonalds NavSta	PSNS015	102.3	5.32E+04	0.0429	0.0361	1.3523	21.1	19.9	27.3	5	1.12	1.06	1.45
168	Stormwater	PSNS FISC	PSNS052	32.2	2.32E+04	0.0013	0.0011	1.8234	35.1	23.7	54.0	0	0.81	0.55	1.26
169	Stormwater	PSNS081.1 Bldg 455 "R" St.	PSNS081	22.5	2.35E+04	0.0056	0.0047	1.5510	59.4	58.5	60.2	2	1.40	1.38	1.42
170	Stormwater	PSNS082.5 Bldg 480	PSNS082	14.7	7.16E+03	0.0012	0.0010	0.5082	35.1	23.7	54.0	0	0.25	0.17	0.39
171	Stormwater	PSNS DD5		41.8	2.27E+04	0.0007	0.0006	1.8179	35.1	23.7	54.0	0	0.80	0.54	1.23
172	Stormwater	PSNS Bldg 457		16.7	1.32E+04	0.0038	0.0032	0.8256	35.1	23.7	54.0	0	0.46	0.31	0.71
173	Stormwater	PSNS "N" St.		11.6	3.04E+03	0.0026	0.0022	0.0692	35.1	23.7	54.0	0	0.11	0.07	0.16
174	Stormwater	PSNS101 Pier 5	PSNS101	11.8	3.04E+03	0.0026	0.0022	0.0692	30.8	30.8	30.8	1	0.09	0.09	0.09
175	Stormwater	PSNS115.1 Dry Dock 1	PSNS115	10.0	2.82E+03	0.0021	0.0017	0.0902	35.1	23.7	54.0	0	0.10	0.07	0.15
176	Stormwater	PSNS124 Dry Dock 3/2	PSNS124	18.0	7.88E+03	0.0014	0.0011	0.5593	138.2	79.2	147.2	5	1.09	0.62	1.16
177[a]	Stormwater	PSNS126 Bldg 460 Pier 8	PSNS126	85.0	5.04E+04	0.0071	0.0060	3.7694	35.1	27.5	47.9	6	1.77	1.39	2.41
178	Stormwater	PSNS Main Gate		9.8	4.03E+03	0.0017	0.0014	0.2164	1.1	1.1	1.1	1	0.0043	0.0043	0.0043
		Total		406.1	2.30E+05	0.073	0.062	13.967					8.71	6.96	11.15

*Cu concentration based on observed data for n>1, estimated for n=0

[a]Basin 177 includes City of Bremerton Park Ave (CSO16)

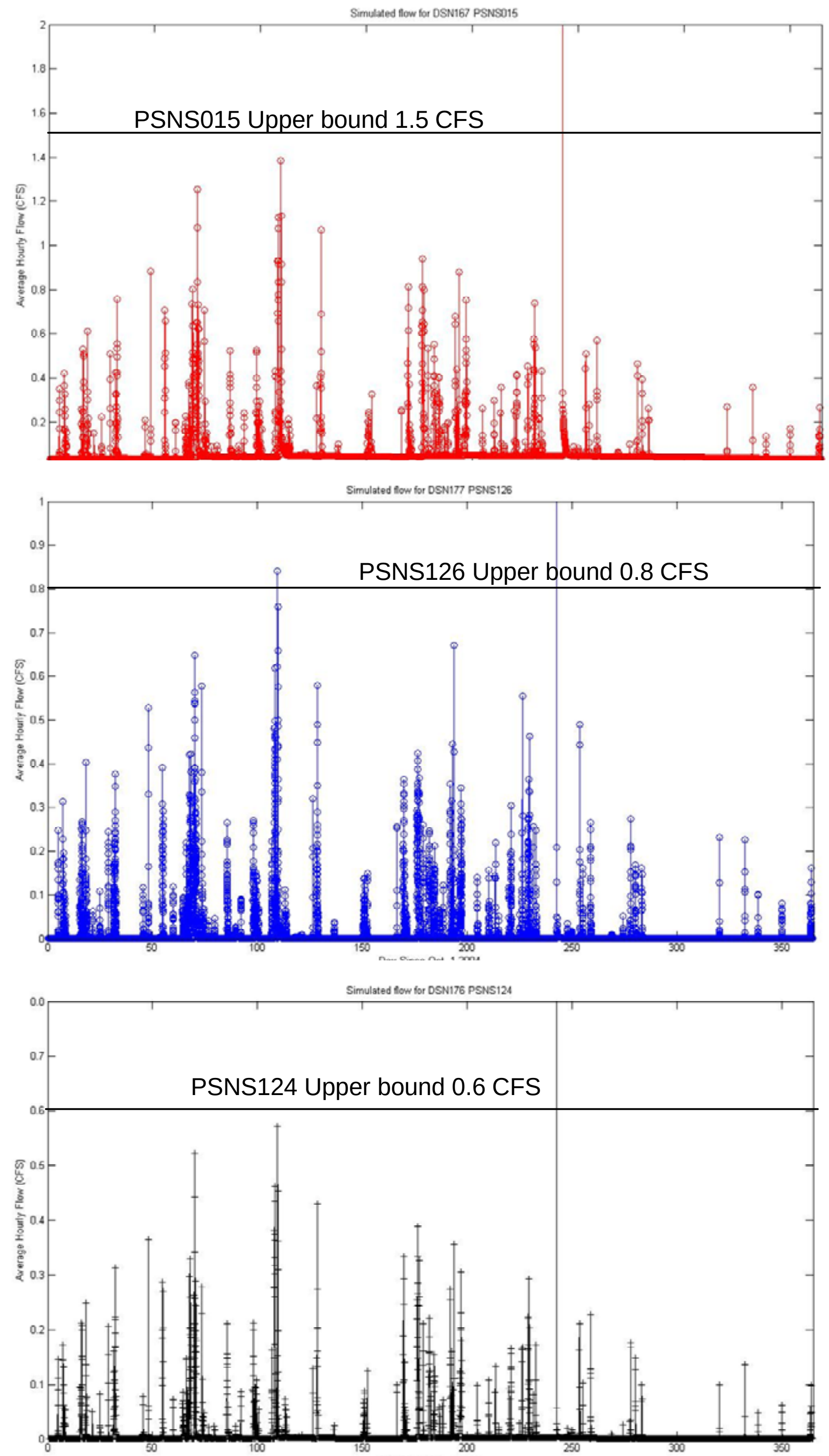


Figure 13. Simulated hourly flows and upper bound of flow rate (average hourly CFS) for selected stormwater basins at PSNS&IMF for WY2005. Note flows for PSNS126 only includes flows from Navy property.

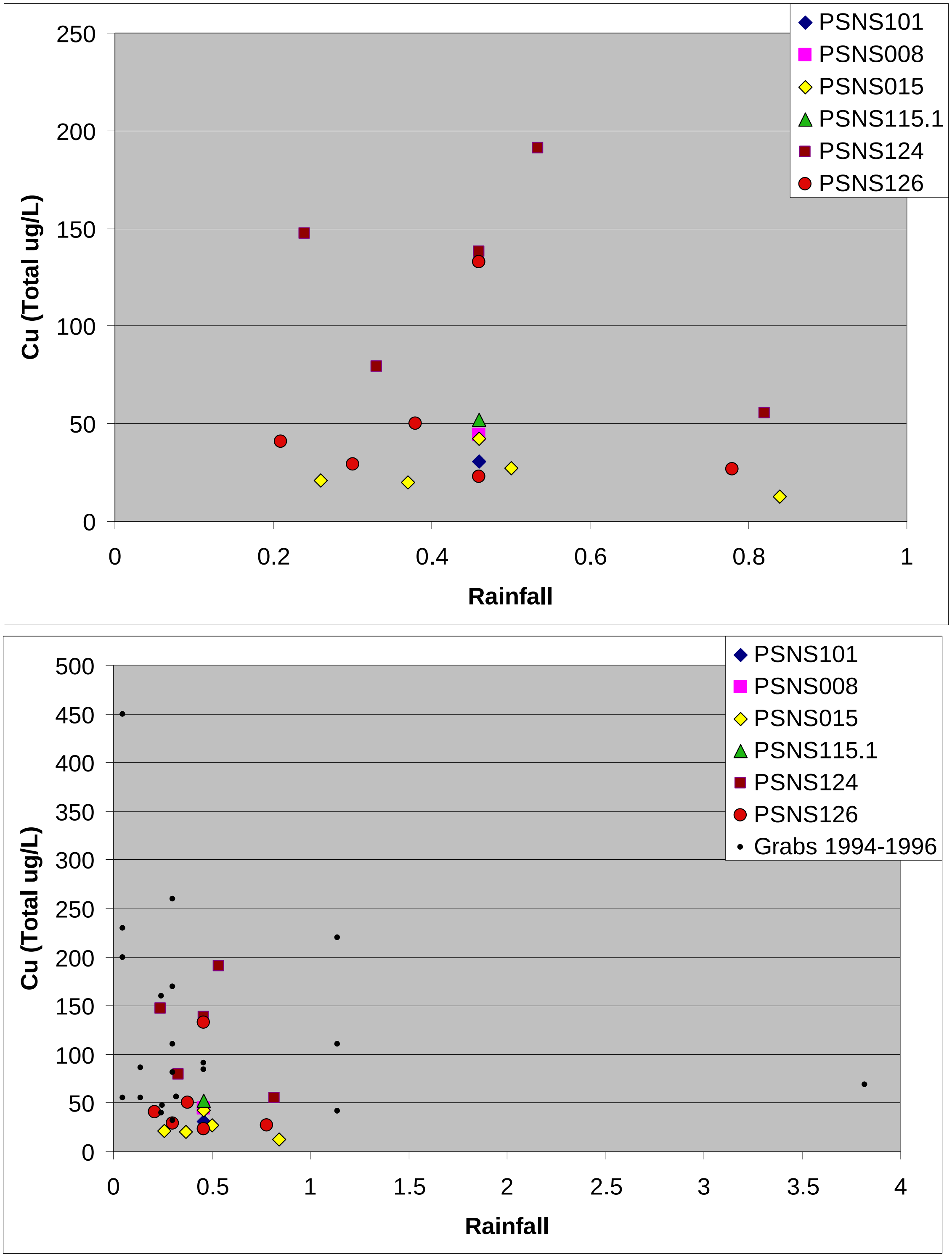


Figure 14. Concentrations of copper measured in stormwater from the Shipyard for event mean concentrations as a function of rainfall sampled during the ENVVEST study (upper panel) and the all stormwater data for the Shipyard including the event mean data from ENVVEST and grab samples taken between 1994-1996 (lower panel).

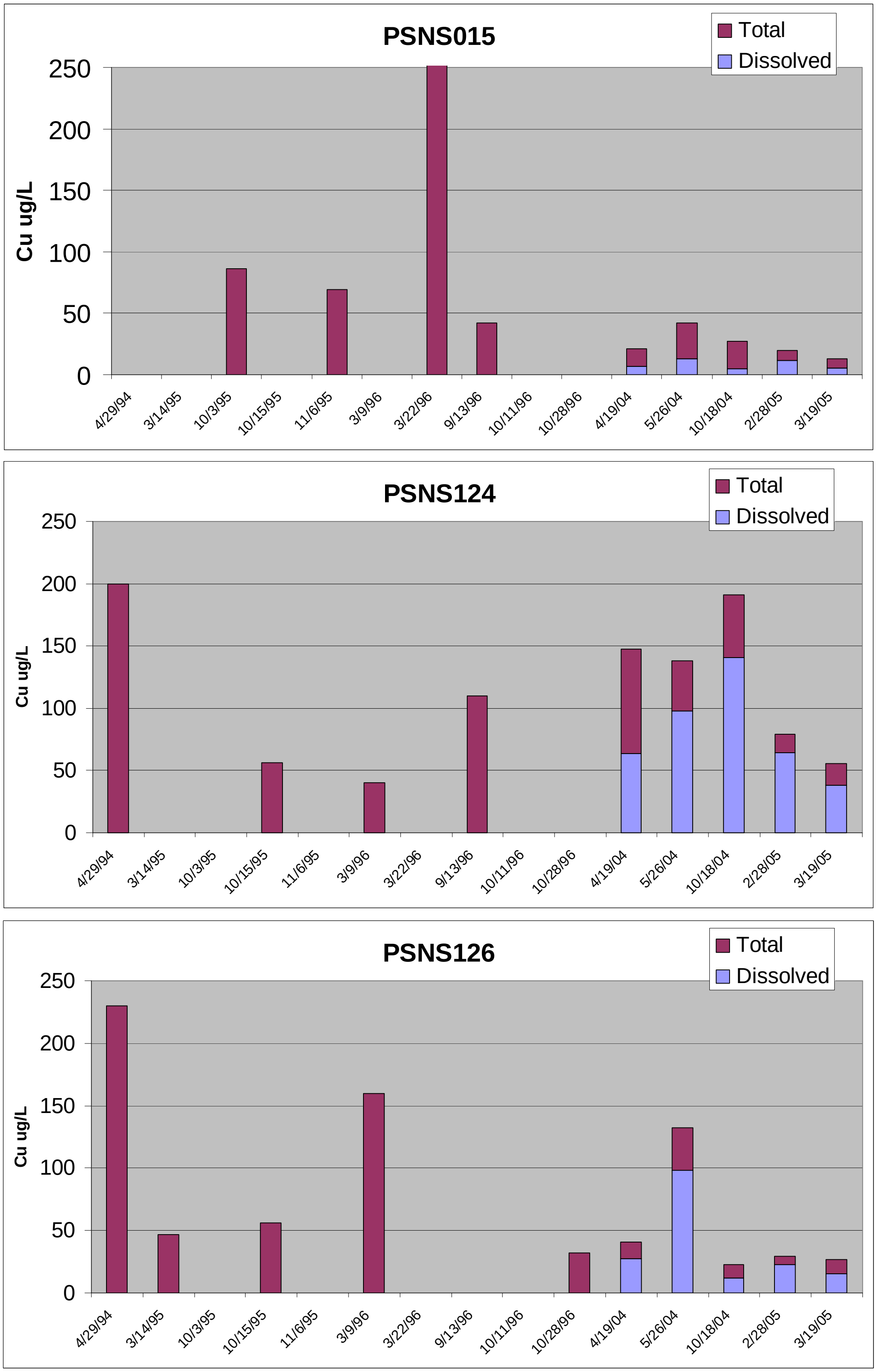


Figure 15. Copper concentrations measured in the three stormwater basins monitored during the ENVVEST studies. Samples collected for ENVVEST from 2004-2005 are event mean concentrations, samples from 1994-1996 are grab samples.

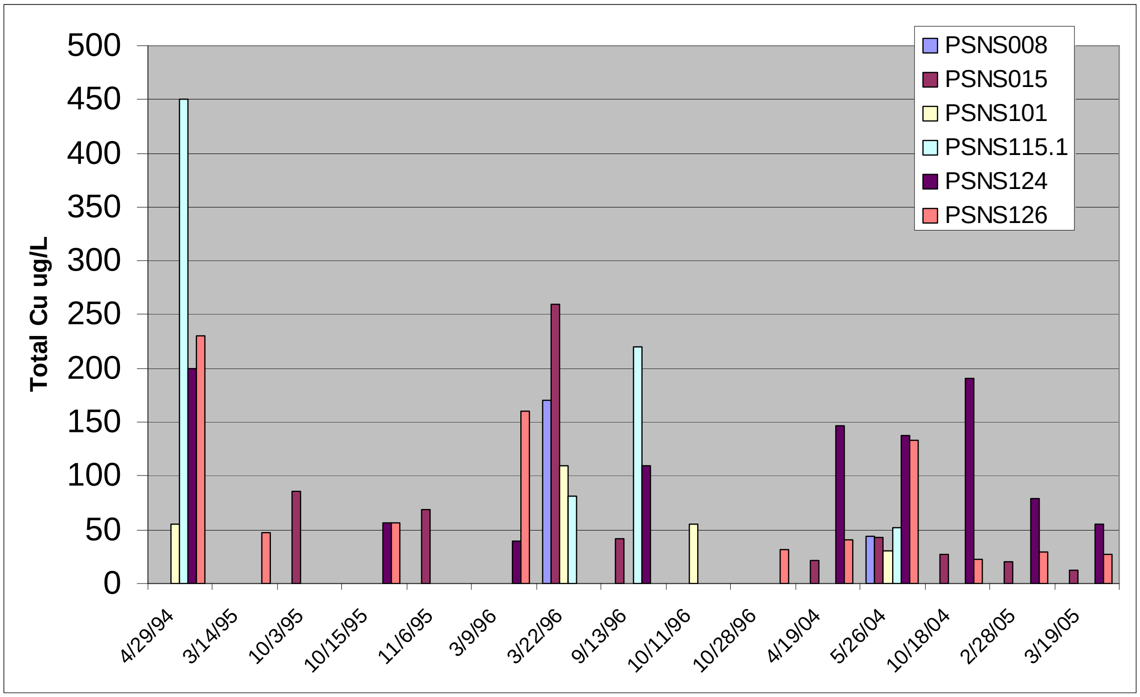


Figure 16. Summary of all stormwater copper concentrations measured in stormwater basins at the Shipyard. Samples collected for ENVVEST from 2004-2005 are event mean concentrations, samples from 1994-1996 are grab samples.

3. MODEL RESULTS

3.1 ESTABLISHMENT AND USE OF MODELING PARAMETERS

For the base run, the following parameters were applied for all outfalls:

- Ambient wind speed (UW) of 0 m/s applied. The effect of wind was omitted in the base run, but can be addressed as part of model sensitivity and uncertainty.
- Ambient velocity (UA) of .0289 m/s was used based The 50 percentile of the measured depth-averaged current from (see Section 2.4.2).
- Ambient Temperature (8.5 ºC) and Salinity (31 ppt) from a 1993 Diffuser Study (AEGI 1993) were used to calculate Ambient Density (RHOAS) 1024.06 kg/m3.
- The value of .022 was applied as a Mannings "n" this is a mathematical description of the relatively smooth, earthen bottom topography of Sinclair inlet.
- Sinclair Inlet is an unbounded waterbody.
- The effluent concentrations of Cu were obtained following the CORMIX modeling requirement to convert Total Cu into dissolved Cu using the dissolved:total translator and subtracting the backgound dissolved Cu concentration (0.818 ppb) (see Section 2.4.3, EQU[1]). For outfalls 18A, 18B, and 19 the Cu concentration was set to 26.572 ppb dissolved Cu, and the stormwater drains were set to 29.361, 78.821, and 143.159 ppb dissolved Cu for PSNS015, PSNS126, and PSNS124, respectively.

For individual outfalls, the following parameters were applied to each outfall scenario (Table 5).

3.1.1 Outfall 18A

3.1.1.1 Effluent conditions

- The effluent flow rate (6,900 gpm) and temperature (14.2º C) are averaged data from daily measured values at the drydock.
- The effluent salinity (17.7 ppt) is applied from the 1993 Diffuser Study (AEGI 1993)
- These values for temperature and salinity were used to calculate a density of 1012.83 kg/m3.

3.1.1.2 Ambient Conditions

- The Average Depth (HA) was set to 30 feet.
- Per the CORMIX modeling requirements, the depth at discharge (21 feet) is artificially controlled by the requirement of a CORMIX 3 modeling run – it must not differ from the average depth by more than + or - 30 percent. There is another entry to specify the actual near-shore depth, just in front of the surface discharge outlet.

3.1.1.3 Discharge conditions

- Schematized as a CORMIX3 (channel-flow) that is 3 meters wide and 0.3 meters deep with a bottom slope of 60º.
- The Horizontal (Sigma) angle of the discharge to the water body is 90º.

3.1.1.4 Mixing Zone Conditions

- The CORMIX requirement to correct the CMC and CCC by subtracting the ambient concentration (0.818) before modeling yields a CMC of 3.98 and a CCC of 2.28 (Copper).

3.1.2 Outfall 18B

3.1.2.1 Effluent conditions

- The effluent flow rate (7,500 gpm) and temperature (14.1º C) are averaged data from daily measured values at the drydock.
- The effluent salinity (17.7 ppt) is applied from the 1993 Diffuser Study (AEGI 1993)
- These values for temperature and salinity were used to calculate a density of 1012.84 kg/m3.

3.1.2.2 Ambient Conditions

- The Average Depth (HA) of 37 feet is from a Navigational Chart (NOAA Chart 18449)
- The depth at discharge is 8.81m (28.9 feet)

3.1.2.3 Discharge conditions

- The nearest bank is 0 m
- The port diameter is .61 m (2 feet) from the NPDES fact sheet
- The Vertical (Theta) angle is 0º and the The Horizontal (Sigma) angle of the discharge to the water body is 90º from the 1993 Diffuser study (AEGI 1933).
- The height of the center of the discharge port above the bottom is 6.52 m according to PSNS Code 980. (see Section 2.2)

3.1.2.4 Mixing Zone Conditions

- The CORMIX requirement to correct the CMC and CCC by subtracting the ambient concentration (.818) before modeling yields a CMC of 3.98 and a CCC of 2.28 (Copper).

3.1.3 Outfall 19

3.1.3.1 Effluent conditions

- The effluent flow rate (16,000 gpm) and temperature (13.1º C) are averaged data from daily measured values at the drydock.
- The effluent salinity (22.5 ppt) is applied from the 1993 Diffuser Study (AEGI 1993)
- These values for temperature and salinity were used to calculate a density of 1016.72 kg/m3.

3.1.3.2 Ambient Conditions

- The Average Depth (HA) of 41 feet is from a Navigational Chart (NOAA Chart 18449)
- The depth at discharge is 8.81m (28.9 feet)

3.1.3.3 Discharge conditions

- The nearest bank is 0 m
- The port diameter is .91 m (3 feet) from the NPDES fact sheet
- The Vertical (Theta) angle is 0º and the The Horizontal (Sigma) angle of the discharge to the water body is 90º from the 1993 Diffuser study (AEGI 1993).
- The height of the center of the discharge port above the bottom is 7.28 m (23.9 feet) according to PSNS Code 980. (see Section 2.2)

3.1.3.4 Mixing Zone Conditions

- The CORMIX requirement to correct the CMC and CCC by subtracting the ambient concentration (.818) before modeling yields a CMC of 3.98 and a CCC of 2.28 (Copper).

3.1.4 Outfall 21- Temperature Modeling

3.1.4.1 Effluent conditions

- The effluent flow rate (175 gpm) is an estimate of the upper flow range from monthly NPDES DMR data
- The Maximum permitted temperature (32º C) is from NPDES permit.
- The effluent is modeled as a heated discharge with a heat loss coefficient of 5 W/m2, deg C. Per the CORMIX model, this is equivalent to a 0 wind speed and an ambient temperature of 5º -20º C
- A worst case (highest temperature, least amount of mixing) modeling run simulated the effluent as a 32º C freshwater discharge and the ambient as 16º C resulting in a excess discharge temperature of 16º C.

3.1.4.2 Ambient Conditions

- The Average Depth (HA) of 13.9 m (44.58) feet is from a Navigational Chart (NOAA Chart 18449)
- The depth at discharge is 10.67m (35 feet)

3.1.4.3 Discharge conditions

The Steam plant discharge is connected to a 40 foot long diffuser that has an 8 inch diameter pipe with approximately five, 3 inch diameter holes discharging horizontally, spaced at 10 feet, alternating sides. The diffuser is at right angles to the shore, starting at 918 feet from shore, at a depth of 35 feet. (see Section 2.4.4)

- The Diffuser length is 12.192m

- The distance to the first endpoint is 279.806m
- The distance to the second endpoint is 291.998m
- The port height is 1.21 m above the bottom
- The port Diameter was set to 0.1 meter
- The contraction ratio was set to 1
- The total number of openings is 5 schematized as alternating single risers (same direction) with a vertical angle (Theta) of 0º
- The alignment angle (gamma) is 90º

3.1.4.4 Mixing Zone Conditions

- A delta temperature of 0.3 ºC was used as the Water Quality Standard.

3.1.5 Storm Drains

The parameter settings for the storm drains are summarized in Table 5. Because stormwater discharges are driven by storm events, only the CMC (acute) mixing zones were calculated for the stormwater basins.

Table 5. Summary of modeling parameters used to model dry dock, storm drains (A), and steam plant (B) discharges.

A. Dry dock discharge and storm drain parameters

						Large	Med	Small
	Parameter	**Units**	**Outfall #018A**	**Outfall #18B**	**Outfall #19**	**PSNS015**	**PSNS126**	**PSNS124**
Effluent	flow rate	m^3/sec	0.44	0.47	1.0094	0.04250	0.02270	0.00340
	Temperature	deg C	14.2	14.1	13.1	10.7	10.7	11.4
	Salinity	ppt	17.7	17.7	22.5	0.472	0.272	2.028
	Calculated Density	kg/m3	1012.8	1012.8	1016.7	1000.1	999.9	1001.2
	Concentration	ppb	26.572	26.572	26.572	29.3608	78.8205	143.1593333
Ambient	Average Depth	m	9.14	11.28	12.4968	11.2776	13.716	8.8392
	Depth at Discharge	m	6.40	8.81	8.80872	11.2776	13.716	8.8392
	Wind Speed	m/s	0.00	0.00	0	0	0	0
	Steady Velocity	m/s	0.0289	0.0289	0.0289	0.0289	0.0289	0.0289
	Manning #		0.022	0.022		0.022	0.022	0.022
	Unbounded		U	U		U	U	U
	Temperature	deg C	8.5	8.5	8.5	8.5	8.5	8.5
	Salinity	ppt	31	31	31	31	31	31
	Density	kg/m^3	1024.06	1024.06	1024.06	1024.06	1024.06	1024.06
Discharge	Nearest Bank		right	right	right	right		
	Distance to nearest bank	m		0	0	0	0	0
	Port Diamter	m		0.6096	0.9144	1.2192	0.6096	0.3048
	Veritcal Theta	deg	0	0	0	0	0	0
	Horizontal Sigma	deg	90	90	90	90	90	90
	Discharge Port Height	m	5.79	6.52	7.28	10.36	13.11	8.38
	Port Width	m	3.05		0.91	1.219	0.6096	0.3
	Port Depth	m	0.30					
	Port Height	m			7.28	10.36	13.1064	8.38
	Bottom Slope	deg	60		60	60	60	60
Mixing Zone	CMC	ppb	3.982	3.982	3.982	3.982	3.982	3.982
	CCC	ppb	2.282	2.282	2.282	2.282	2.282	2.282

B. Steam Plant Discharge Parameters

Outfall 21	Parameter	Units
Flow Rate	0.0110408	m3/s
Effluent Density (Temperature)	32	ppb
Heat Loss Coefficient	5.00	W/m2, deg C
Discharge Temperature (Excess)	16	deg C
Depth at Discharge	10.67	m
Wind Speed	0	m/s
Steady Velocity	0.0166	m/s
Manning #	0.022	
Unbounded	U	
Temperature	8.5	deg C
Salinity	31	ppt
Density	1022.67	kg/m^3
Diffuser length	12.192	m
Dist. to 1st endpoint	279.806	m
Dist to 2nd endpoint	291.998	m
Port Height	1.2192	m
Port Diameter	0.100584	m
Contraction Ratio	1	
Total # of openings	5	
Alignment Ang GAMMA	90.00	deg
Configuration of Ports or Nozzles	Single Riser, alternating	
Vertical- Theta	0	deg
Direction of nozzles on each side	Same direction	
Concentration for the WQ Standard (excess)	0.3	deg C

3.2 MODELING RESULTS

The summary of CORMIX modeling results for the dry dock, stormwater, and steam plant discharges are summarized in Table 6. The details of the modeling results are described below.

Table 6. Summary of CORMIX model results for dry dock, stream plant, and stormwater discharges.

Results for Cormix modeling			Distance from Outfall			Dilution Factor	Mixing Zone			
Outfall	Criterion	Effluent Concn. ppb TR Cu	X (Parallel to the discharge) meters	Y (Perpendicular to the discharge) meters	Z (depth from surface) meter	Hydrodynamic centerline dilution dilution Factor	Centerline Conc. Dissolved	units	Trajectory meters	Trajectory feet
Dry Docks .										
Outfall 18A*	**Dilution Factor of 3**	33.0	0.24	9.98	0.00	3.00	8.93	ppb Cu	9.98	32.75
	CMC HAS BEEN FOUND	33.0	5.32	49.03	0.00	6.67	3.98	ppb Cu	49.32	161.80
	CCC HAS BEEN FOUND	33.0	508.23	0.00	0.00	11.70	2.28	ppb Cu	508.23	1667.42
	Dilution Factor of 10.3**	33.0	208.76	0.00	0.00	10.30	2.57	ppb Cu	208.76	684.91
Outfall 18B	**Dilution Factor of 3**	33.0	0.12	7.31	8.81	3.00	8.87	ppb Cu	7.31	23.99
	CMC HAS BEEN FOUND	33.0	0.78	18.40	8.81	6.67	3.98	ppb Cu	18.42	60.42
	CCC HAS BEEN FOUND	33.0	2.60	32.51	8.81	11.60	2.28	ppb Cu	32.61	107.00
	Dilution Factor of 9	33.0	1.49	25.04	8.81	9.00	2.97	ppb Cu	25.08	82.30
Outfall 19	**Dilution Factor of 3**	33.0	0.69	16.45	8.81	3.20	8.93	ppb Cu	16.46	54.02
	CMC HAS BEEN FOUND	33.0	4.36	39.29	8.81	6.67	3.98	ppb Cu	39.53	129.70
	CCC HAS BEEN FOUND	33.0	12.33	62.07	8.81	11.60	2.28	ppb Cu	63.28	207.62
	Dilution Factor of 9	33.0	7.79	50.96	8.81	9.00	2.96	ppb Cu	51.55	169.13
Stream Plant .										
Outfall 21	**CCC HAS BEEN FOUND**		0.58	0.00	6.11	53.30	0.30	° C	0.58	1.90
Stormwater Depth at Discharge 6 ft										
PSNS015	**CMC HAS BEEN FOUND**	36.36	1.51	0	11.28	7.37	3.98	ppb Cu	1.51	4.95
PSNS126	**CMC HAS BEEN FOUND**	95.95	287.13	0	13.72	19.79	3.98	ppb Cu	287.13	942.03
PSNS124	**CMC HAS BEEN FOUND**	173.47	34.43	0	8.84	35.951	4.80	ppb Cu	34.43	112.96
Stormwater Depth at Discharge 1 ft										
PSNS015	**CMC HAS BEEN FOUND**	36.36	235.26	0	11.28	7.37	3.98	ppb Cu	235.26	771.85
PSNS126	**CMC HAS BEEN FOUND**	95.95	1820.09	0	13..72	37.48	3.98	ppb Cu	1820.09	5971.42
PSNS124	**CMC HAS BEEN FOUND**	173.47	656.46	2	8.84	35.951	3.98	ppb Cu	656.46	2153.75

*CORMIX3 module used
**Model jumps

3.2.1 Outfall 18A

Changes in tidal conditions result in Outfall 18A occasionally discharging above the waterline and set back from the shoreline. The worst case (i.e. least amount of mixing) conditions occur when this discharge occurs during low tide. During the discharge, the effluent hits a backflow valve at the quay wall creating a spray pattern onto the nearby rocks as it exits the outfall and flows down the riprap to Sinclair Inlet. The best CORMIX approximation to this discharge configuration is a CORMIX3 run simulating a shallow, wide channel, flowing into the water body. CORMIX does not allow for a channel that is less than 0.3 meters so this was used as the default value. The discharge is characterized as a flow with no bank interaction or bottom interaction in the near-field, and the buoyancy is relatively strong significantly distorting the cross-section of the flow in the near-field. Modeling an initial discharge of 26.572 ppb copper, the CMC is met approximately 49.32 meters from the initial discharge point (Table 6).

3.2.2 Outfall 18B

This submerged discharge is located 6.52 m above the channel bottom and the discharge is flush with the quay wall. The discharge is characterized as a slightly submerged, positively buoyant effluent horizontally from the discharge port. The discharge is cross-flowing with respect to the ambient current. Using the parameters in Table 5, the CORMIX1 simulation with an initial discharge of 26.572 ppb copper showed that the CMC was met approximately 18.42 meters from the initial discharge point (Table 6).

3.2.3 Outfall 19

This submerged discharge is located 7.28 m above the channel bottom and the discharge is flush with the quay wall. The discharge is characterized as a slightly submerged, positively buoyant effluent horizontally from the discharge port. The discharge is cross-flowing with respect to the ambient current. Using the parameters in Table 5, the CORMIX1 simulation with an initial discharge of 26.572 ppb copper showed that the CMC was met approximately 39.53 m from the initial discharge point (Table 6).

3.2.4 Outfall 21

This discharge is a 0.1 m pipe with a 12.1m long diffuser starting 279.8m from the shore at a depth of 10.67m. CORMIX simulates discharges with alternating ports or nozzles with no directed net momentum input. The dilution is dominated by the buoyancy characteristics of the discharge and by the ambient current conditions. A worst-case scenario model run to look at temperature differences was configured. The 0.011 m^3/sec flow rate is an estimate of the highest flow rate that would occur as well as a maximum discharge temperature of 32 ºC. Using the parameters in Table 5, the CORMIX2 run determined that the water quality standard of +/-0.3 ºC from ambient (for ambient temperatures over 16 ºC) is met approximately 0.58 m from the initial discharge point (Table 6).

3.2.5 Stormwater Modeling

An attempt was made to model all the stormwater discharges from the Shipyard by configuring CORMIX2 to simulate a shallow, multiport discharge parallel to the shoreline with the number of ports equal to the number of stormwater outfalls along each watershed subsection (drainage basin). Another configuration that was attempted was to schematize the shoreline as a CORMIX 3 model run with a very shallow and wide channel. These simulations failed for a number of reasons and after consultation with Dr. Robert L. Doneker (the inventor of the CORMIX model) it was determined that:

1. Modeling a number of point sources along the shoreline as a multiport discharge line source is not be a adequate representation of the mixing behavior especially if the individual plumes do not merge in the near-field.
2. There is not enough information to properly characterize each individual discharge including the velocity, flow rate, and volume in order to configure a multiport discharge scenario.
3. CORMIX specifically disallows the use of a shallow, wide channel for modeling because the appropriate momentum and mixing modules do not exist to support this type of configuration.

Therefore, three drainage basins representative large, medium, and small stormwater discharges were modeled to bracket the range of stormwater plumes expected from the Shipyard and calculate the mixing needed to meet water quality standards. The effluent concentrations were set to the event mean Cu concentration estimated from the ENVVEST data and the flow rates were set to the upper bound hourly flow rate modeled for each basin (see Section 2.4.5 Stormwater Data). Assuming that the storm drains discharged at 6 ft below the surface, the simulation results showed that the CMC was met at 1.51 m, 287.13 m, and 34.43 m for the large (PSNS015), medium (PSNS126), and small (PSNS124) basins, respectively. Since stormwater discharges are driven by storm events which are unlikely to exceed 96 hr of continuous rainfall, the CMC (acute) mixing zones were assumed to be protective of discharges from the storm drains. Considerably larger mixing zones were required when it was assumed that the stormwater drains discharged at a depth of 1 ft (Table 6).

The accuracy of the CORMIX results obtained for the storm drain discharges are questionable. While the CORMIX model was used to model "hypothetical" stormwater discharges, the CORMIX model is not designed to model surface discharges with low momentum. CORMIX is designed to simulate discharges with much higher flow rates than those associated with stormwater discharges. Typically, CORMIX is designed to simulate discharge velocities of 3.0 – 8.0 m/s, with 0.5 m/s being "very low velocity," which are about an order of magnitude higher than the stormwater discharges of 0.04 – 0.08 m/s calculated for the PSNS&IMF stormwater discharges. Additional the Technical Support Document (TSD) for Water-Quality-based Toxics Control (USEPA 1990) recommends that the toxic dilution zone encompassed within the regulatory mixing zone will meet at least one of the four following criteria:

1. Meet the CMC within the discharge pipe
2. Exit velocity must exceed 3 m/s (10 ft/sec)
3. Geometric restrictions must be satisfied, and

4. Show that a drifting organism will not be exposed to the CMC for more than 1 hr no more than once in 3 years.

These criteria were not met for any of the stormwater simulations conducted and warnings about the discharge configuration were included in the CORMIX session report generated for the stormwater simulations (Table 7). The CORMIX simulations of stormwater discharges (particularly the 1 ft deep discharges) resulted in extremely low velocity plumes that stayed on the surface, came into contact with the nearest bank, and stretched out in shallow ribbons that remained nearby the outfall for indefinite periods. It is very unlikely that this type of plume behavior would occur under real world conditions.

Table 7. Summary of the warnings generated in the session report from the simulation of PSNS126 discharging at a depth of 6 ft.

```
PLUME BANK CONTACT SUMMARY:
  Plume in unbounded section contacts nearest bank at 0.69 m downstream.
*********************** TOXIC DILUTION ZONE SUMMARY ***********************
Recall: The TDZ corresponds to the three (3) criteria issued in the USEPA
  Technical Support Document (TSD) for Water Quality-based Toxics Control,
  1991 (EPA/505/2-90-001).
  Criterion maximum concentration (CMC)  = 3.982  ppb
Corresponding dilution                   = 19.794324
The CMC was encountered at the following plume position:
  Plume location:                       x = 287.13 m
    (centerline coordinates)            y = 0 m
                                        z = 13.72 m
  Plume dimension:       half-width (bh) = 158.24 m
                          thickness (bv) = 0.10 m

 Computed distance from port opening to CMC location = 287.14 m.
 CRITERION 1: This location is beyond 50 times the discharge length scale of
              Lq = 0.54 m.
 +++++ The discharge length scale TEST for the TDZ has FAILED. ++++++

 Computed horizontal distance from port opening to CMC location = 287.13 m.
 CRITERION 2: This location is beyond 5 times the ambient water depth of
              HD = 13.72 m.
 ++++++++++ The ambient depth TEST for the TDZ has FAILED. ++++++++++

 Computed distance from port opening to CMC location = 287.14 m.
 CRITERION 3: This location is beyond one tenth the distance of the extent
              of the Regulatory Mixing Zone of 59.43 m in any
              spatial direction from the port opening.
 +++++ The Regulatory Mixing Zone TEST for the TDZ has FAILED. ++++++

 The diffuser discharge velocity is equal to 0.08 m/s.
 This is below the value of 3.0 m/s recommended in the TSD.

 *** This discharge DOES NOT SATISFY all three CMC criteria for the TDZ. ****
 **** This MAY be caused by the low discharge velocity for this design. *****
********************** REGULATORY MIXING ZONE SUMMARY **********************
The plume conditions at the boundary of the specified RMZ are as follows:
  Pollutant concentration               c = 4.937321  ppb
  Corresponding dilution                s = 16.0
  Plume location:                       x = 59.40 m
    (centerline coordinates)            y = 0 m
                                        z = 13.72 m
  Plume dimensions:      half-width (bh) = 73.64 m
                          thickness (bv) = 0.17 m
Cumulative travel time:       2053.9375 sec.
At this position, the plume is CONTACTING the RIGHT bank.
However, the CCC for the toxic pollutant has not been met within the RMZ.
 In particular:
The CCC was encountered at the following plume position:
The CCC for the toxic pollutant was encountered at the following
  plume position:
  CCC                                     = 2.282  ppb
Corresponding dilution                    = 34.5
  Plume location:                       x = 1485.62 m
    (centerline coordinates)            y = 0 m
                                        z = 13.72 m
  Plume dimensions:      half-width (bh) = 338.45 m
                          thickness (bv) = 0.08 m
******************** FINAL DESIGN ADVICE AND COMMENTS *********************
INTRUSION OF AMBIENT WATER into the discharge opening will occur.
  For the present discharge/environment conditions the discharge densimetric
  Froude number is well below unity.
  This is an UNDESIRABLE operating condition.
  To prevent intrusion, change the discharge parameters (e.g. decrease the
  discharge opening area) in order to increase the discharge Froude number.
```

3.3 ALTERNATIVE APPROACHES

3.3.1 Dye Study

The Technical Support Document (TSD) for Water-Quality-based Toxics Control (USEPA 1990) recommends dye studies as an acceptable alternative to hypothetical modeling studies in determining discharge mixing zones. The ENVVEST Studies included a dye study of drydock discharges from the Shipyard (Katz et al. 2004b, Katz and Blake 2004). The dye study measured the amount and spatial extent of dilution of discharges from the dry docks under normal operational conditions as the discharges mixed into Sinclair Inlet. The approach taken was to add known amounts of fluorescent dye to dry dock discharges and measure its concentration once it is mixed with the adjacent receiving waters. Dye measurements were made at a fixed point near to the discharge point to determine the minimum dilution in the plume. The spatial distribution of dye was also mapped as a function of time to assess the full spatial extent of mixing over a range of tide conditions.

> "Normal dry weather discharge of ground water mixed with dye from dry docks 6 and 4 was successfully mapped in the adjacent inlet waters during both flood and ebb tide conditions. The discharge plumes rose to the surface relatively quickly after leaving the discharge pipe because of their lower density relative to the surrounding inlet water. Plume water reached the surface within several meters of its discharge from Pump Well 6 underneath pier 9. The plume surfaced about 30 m out from quay wall (~40 m from the end of pipe) from Pump Well 4. The increased distance away from Pump Well 4 was presumably a result of a higher discharge velocity through a special check valve unit.
>
> At Pump Well 6, the "boil" region was diluted by only a factor of 1.5 whereas the boil off Pump Well 4 was diluted by a factor of 7. However, there was a relatively quick and efficient mixing of the plumes at both locations once they reached the surface. Background levels were typically reached within 100 m or so of where the plumes surfaced. Dilution factors of between 100 and 1000 were reached while still within the confines of shipyard security boundary off Pump Well 6 and well within the confines of the piers off Pump Well 4. Average dilution factors in the boxed areas outside each outfall (Figure 8 and Figure 9) ranged between 200 and 1000.
>
> While there was clearly some advective flow that mixed the plumes out from the “boil” region, the majority of the mixing occurred while spreading at the surface. In some instances the advective flow resulted in patchiness of the distribution but the principal variability in the spatial distributions was a result of sampling at different stages in the pump cycle rather than tidal flow. There was a slight buildup in background levels of dye with successive pump cycles in the immediate region of the surface "boil" though there was no clear relationship between tide stage and the build up. "

- excerpt from Executive Summary in Katz and Blake (2004)

The results from the dye study of the dry dock outfalls indicate that the CORMIX simulations are probably more conservative than the actual discharge conditions which reached background concentrations (i.e. concentrations that would be much lower than the CMC or CCC) within 100 m of where the plumes surfaced.

3.3.2 Copper Toxicity Study

As part of the ENVVEST Studies, the toxicity and bioavailability of copper in Sinclair Inlet was evaluated by spiking ambient water samples from Sinclair and Dyes Inlets with various concentrations of copper prior to conducting laboratory bioassays with mussel embryos (Rosen et al. 2004a, 2006).

> "Ambient site water samples were collected in spring, winter, and late summer/fall and tested for toxicity to mussel (*Mytilus galloprovincialis*) embryos in 48-hour embryo-larval development tests using protocols recommended by the U.S. Environmental Protection Agency (EPA) for calculating water-effect ratios (WER). The ambient water samples from Sinclair and Dyes Inlets were not toxic to mussel embryos during the tests, and had dissolved copper concentrations (range = 0.6 – 2.1 µg/L) that averaged three times lower than the ambient water quality criteria (AWQC) for continuous (3.1 µg/L [chronic limit]) and over 4 times lower than maximum (4.8 µg/L [acute limit]) exposure. Reduced normal survival of mussel embryos was observed in two samples from the late summer/fall sampling event, but the toxicity was attributed to the presence of very high concentrations (> 105 cells/L) of a toxic dinoflagellate, *Gymnodinium splendens*, rather than exposure to contaminants associated with industrial discharges.
>
> Copper additions to site and laboratory waters always resulted in toxic effects to developing mussel larvae. The measured copper concentration causing an effect in 50% of the test animals (EC_{50}) in the site water toxicity tests was always higher than EC_{50}s generated in laboratory water comparable to that used in AWQC development. As expected, total recoverable EC_{50} values were significantly correlated with total suspended solids, and dissolved EC_{50}s were significantly correlated with dissolved organic carbon concentration. Final dissolved and total recoverable WERs of 1.41 and 1.63 were calculated, respectively, following the determination of no statistical differences among individual WERs across sampling seasons and among the sampling locations within a sampling event. These findings indicate that overall conditions within the Inlets were responsible for reducing the toxicity of copper to mussel embryos by a factor of 1.41, on a dissolved basis. Therefore, an adjustment of the national AWQC for dissolved copper by a factor of 1.41 would still provide the level of protection intended by USEPA. Using this WER, acute and chronic site-specific dissolved copper criteria for Sinclair and Dyes Inlets, would be 6.8 and 4.4 µg/L, respectively.
>
> Developmental tools that show promise as a means of predicting WERs using various rapidly obtained measurements were also evaluated in this study. Models based on the linkages between toxicity and dissolved organic carbon (DOC) concentration, free copper ion concentration (pCutox) and copper complexation capacity (CuCC), a chemical measure of bioavailability based on free copper measurements, correlated well with copper effect levels (EC50)(r2 =0.6 to >0.7). Empirically derived (toxicity test-based) WERs from this study were within 5% of those predicted using these models. The development tools also allowed for the prediction of similar final WERs (range = 1.27 to 1.40) using larger sample sizes (n=117 for DOC, n=26 for pCutox and CuCC) than that used for the toxicity study (n=13). The similarity between empirically derived and predicted WERs using the DOC model both supports the results of the toxicity study and helps validate these

models as effective and less costly means of deriving site-specific criteria for copper in saltwater environments. Because of the availability of a toxicity test-derived WER, and the current regulatory acceptance of that method, we advise that modifications to the state water quality standard and/or NPDES permits be based on those results.

The very high sensitivity of *M. galloprovincialis* embryos to relatively low concentrations of dissolved copper makes it a relevant test endpoint on which to base a WER study. Recent studies indicating high copper sensitivity to salmonid endpoints (e.g. olfactory inhibition) were generally conducted in waters with characteristics appreciably different than those expected in Sinclair and Dyes Inlets. Use of the Biotic Ligand Model to normalize toxic concentrations based on expected site-specific conditions (e.g. hardness, DOC concentrations) indicate that these endpoints would be adequately protected under a site-specific criterion based on the *M. galloprovincialis* results." - excerpt from Executive Summary of Rosen et al. (2006)

Currently, the ENVVEST program is collaborating with NOAA Fisheries Northwest Fisheries Science Center (NFSC)'s investigation of Cu effects on Chinook smolts in saltwater from Puget Sound. Samples collected during July/August 2008 study conducted at NFSC's Mukeltio Lab were analyzed to provide additional data on saltwater chemistry and toxic effects to mussel (*Mytilus galloprovincialis*) embryos in the same source water used for the Chinook smolt study. It is anticipated that the results of this study would provide a direct comparison of the relative sensitivity of juvenile Chinook smolts and mussel larvae to Cu exposure in salt water (ENVVEST 2009).

3.3.3 High Resolution Dynamic Modeling

As part of Project ENVVEST a 3-D, time dynamic modeling framework, CH3D, has been coupled to a watershed model (HSPF) and is capable of modeling the full range of hydrodynamic mixing from tidal forcing and estuarine flows (Wang and Richter 2002). The modeling framework is capable of modeling all sources and sinks of Cu in the estuarine system including hull releases, cooling water discharges, industrial outfalls, and surface water inputs from the watershed (Table 8, Johnston et al. 2009, in prep). More importantly, the CH3D modeling results can be verified with actual monitoring data to assure that all loads are accounted for and provide a more defensible assessment of whether discharges to the Inlets will impact water quality standards. This approach is consistent with calculating TMDL and setting wasteload and load allocations under the Clean Water Act and similar to the approach being used in support of the TMDL of fecal coliform in Sinclair and Dyes Inlets including the tributary streams (Johnston et al. 2008, in press).

Presently, the Navy is completing a model verification study of copper loading from all sources in Sinclair and Dyes Inlet, using CH3D-CU, a version of CH3D containing a module to simulate copper speciation and running on high resolution grid in the vicinity of the Shipyard (Figure 17). The CH3D-CU simulates dynamic loading from all sources in the watershed (Table 8), models speciation and partitioning of copper in marine waters, and assesses the impact of copper loading during wet (storm events) and dry conditions on water quality standards in the Inlets (Johnston et al. 2009, in prep). This work is scheduled to be completed by September 2009. Upon successful verification of the copper model (CH3D-CU), the copper model could be used simulate specific discharge scenarios to inform the NPDES permit process.

Calculating dilution using a Lagrangian transport solution is also possible. Dilution of storm water discharges near the Shipyard in Sinclair Inlet can be simulated using the use of CH3D model output coupled with a Lagrangian transport module. Discharges out of the pipe may undergo initial mixing stages, during which the initial buoyancy and momentum of the discharges would mix with the ambient Inlet water before they reach an equilibrium position in the water column. Most of the storm water discharges near the Shipyard are expected to be weak or moderate, thus the initial mixing period is short and equilibrium is reached relatively quickly. Once the discharges reach the equilibrium, they are subject to the hydrodynamic transport within the Inlet. The discharges can be simulated as a group of particles (e.g., 10,000-100,000 particles in proportion to the mass of discharge) to be released at the outfall location during the initial mixing period (1 hr for acute, 96 hr for chronic). Contaminant concentration (mass) of the discharge can be evenly distributed among the particles, and each particle represents a normalized fraction (i.e. 1/10000 – 1/100,000) of the initial contaminant concentration (mass) of the discharge. The output from the CH3D hydrodynamic model can be used to predict current velocities (both speed and direction) at each point of the model grid. Lagrangian transport of each particle can be simulated by interpolation of the current velocity field from the model. Therefore, each particle would be transported by the current velocity at each location of the particle at each time step and the simulation would calculate the trajectories of each particle. At each time step, concentration within a defined area or volume can be calculated by dividing the total number of particles the area or volume of interest. In this manner, the CH3D with the Lagrangian transport module can simulate the trajectories (t, x, y, z) of each individual particle and translate their distribution into concentration.

Table 8. Summary of total copper annual load from all sources within the Sinclair and Dyes Inlet watershed (Johnston et al. 2009, in prep).

		Total Copper		
		T_Cu kg/yr		
		Median	25th%	95th%
Navy				
Hull Leaching				
	Active Ships	369.2		
	Service Craft	329.8		
	Inactive Ships	344.0		
Cooling Water Discharge				
	Active Ships	106.7		
NPDES Discharge				
	OF18&19	31.2		
	OF19	77.0		
	Navy Sub-Total	1257.9		
Civillian				
Hull Leaching				
	Museum (Turner Joy)	23.1		
	Marinas			
	Winter	133.1		
	Summer	242.8		
WWTP				
	Bremerton	36.5		
	Karcher Creek/PO	15.4		
	Civilian Sub-Total	450.9		
Watershed Runoff				
	Shipyard Stormwater (DSNs 166-178)	8.7	7.0	11.1
	Stormwater	40.4	17.7	76.7
	Stream/Shoreline	140.9	96.1	208.9
	Watershed Sub-Total	189.9	120.8	296.7
	TOTAL	**1898.8**		

Precentage of Total	
Shipyard Stormwater	0.46%
Shipyard Outfalls	5.70%
Total Shipyard	6.16%
Active Ships & Surface Craft	42.43%
Inactive Ships	18.12%
Total Navy	66.71%

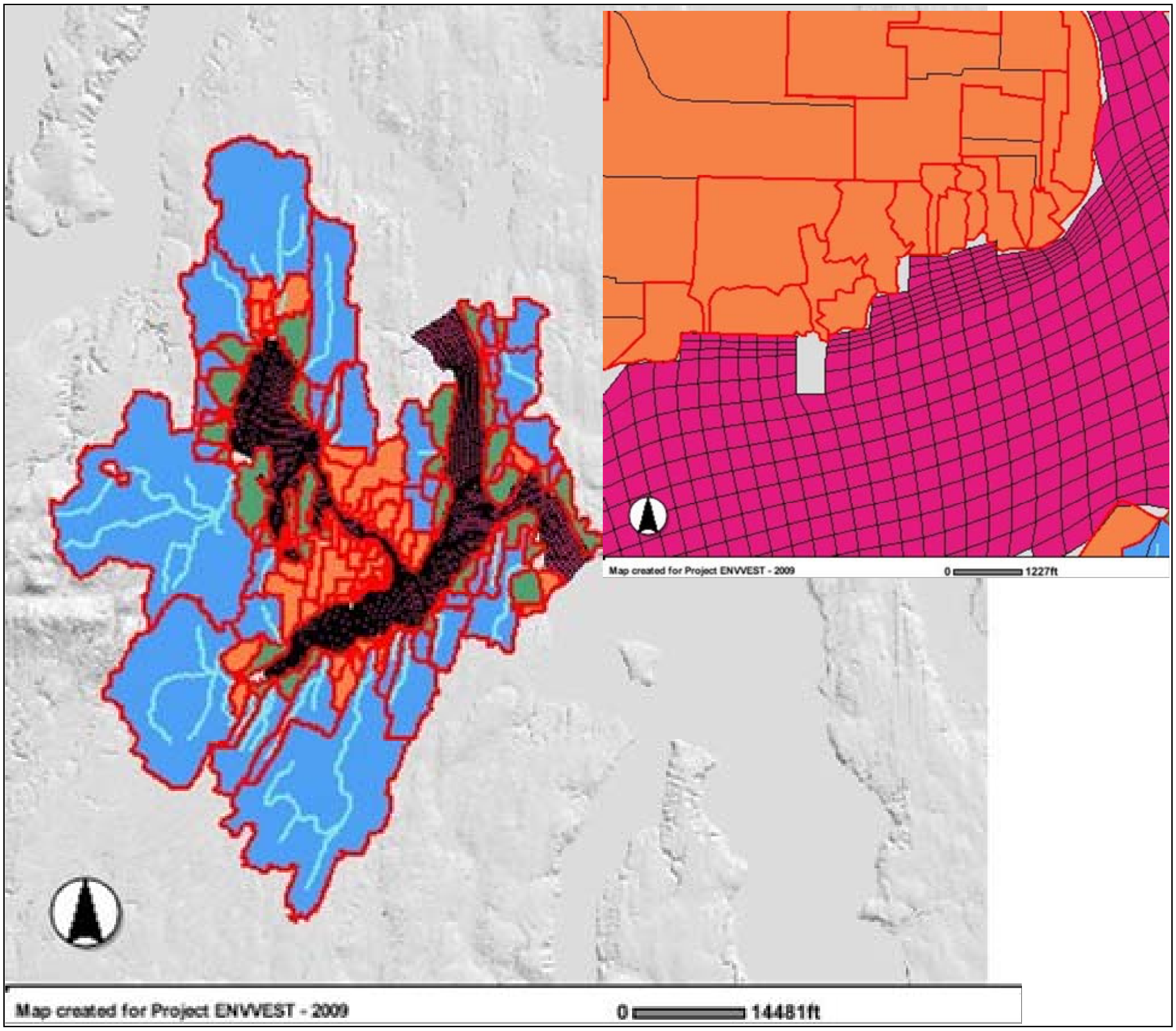


Figure 17. Coupled watershed (HSPF) and estuarine (CH3D-FC) model for Sinclair and Dyes Inlets showing high resolution (96x104) grid for Sinclair and Dyes Inlets, with about a 30-50 m resolution for the area around the Shipyard (inset).

4. UNCERTAINTY

The hypothetical simulations of industrial and stormwater outfalls from the Shipyard were conducted to evaluate the nature of industrial and stormwater discharges and provide information on boundary interactions, steady-state mixing behavior, and plume geometry under theoretical conditions that would inform the permit development process. In these simulations it was necessary to neglect the effects of tidal action, intermittent discharges, the complex geometry present near the outfall discharges, over-lapping discharge plumes, and recirculation (estuarine) flow. In addition, other sources of Cu within the Inlets were not included in the discharge scenarios simulated. Therefore, the CORMIX results reported in this document are provided to inform the permit development process and do not represent actual conditions present in the receiving waters of the Inlets.

The model results for OF 19 were used to evaluate the effect of changing key parameters on the size of the mixing zone. The factors evaluated were:

- background concentration (increase background dissolved Cu concentration from 0.818 to 1.5 ug/L)
- ambient current speed at discharge location (increase ambient current speed from 0.3 cm/s to 10 cm/s)
- wind speed (increase wind speed from 0 to 10 m/s)

All other parameters were held constant. These parameters were selected because it was recognized that variations in these inputs were warranted and could have a bearing on determining the size of the mixing zone.

The results of the sensitivity analysis are summarized in Table 9. Increasing the background concentration to 1.5 ppb dissolved Cu (183% increase) increased the size of the mixing zone by 20 – 35 ft. As the background concentration approaches the water quality standard, the size of the mixing zone would go to infinity, as mixing zones would not be appropriate if the background concentration is near or above water quality standards. However, small variations in background concentration (< a factor of 2) did not greatly affect the sized of the mixing zone. The variation in the available ambient data ranged from 0.044 – 2.6 ppb dissolved Cu, which included storm events and dry periods under a variety of loading conditions in the Inlets.

Increasing wind speed from 0 m/s to 10 m/s did not have any impact on the size of the mixing zone, therefore effects from wind can be ignored.

Increasing current speed from 0.3 cm/s to 10 cm/s (3460% increase) reduced the size of mixing zone by about 97%. The current speed of 10 cm/s is similar to the upper range of currents measured in the surface bin at the current meter station in the Shipyard (90th percentile 12.6 cm/s, max 25 cm/s, Table 2). Obviously, because the current speeds are tidally driven, the ambient currents will range from slack to max speed during every tidal cycle. Additionally, the current monitoring station was located within the Shipyard where current speeds are most restricted near outfalls 18A and 18B (Figure 8), so current speeds at the other outfalls would be higher (especially at OF 19).

Changing both current speed and background conditions also resulted in mixing zones that were about 97% smaller than the base simulation (Table 9).

Further increasing uncertainty is fact that the major storm drains discharge to Sinclair Inlet below mean lower low tide, and, because the Shipyard is only a few feet above high tide, most of the stormwater piping is tidally influenced. This means that mixing is occurring inside the pipes. During high tide the stormwater system is purged with Inlet water effectively preventing the stormwater from draining until the tidal elevations drop.

Probably, the biggest source of uncertainty is the fact that the CORMIX analyses did not include any other sources of Cu in the Inlet. Because there are such a wide range of spatial and temporally varying inputs of Cu from Navy as well as civilian sources (Table 8), the mixing analysis really needs to address the cumulative impacts of the many sources of Cu in the Inlets. This is a prime example of the need for a TMDL approach to determine the amount of Cu that can be discharged into the Inlets without causing the Inlets to exceed water quality standards. While the NPDES permitting process is primarily focused on setting concentration limits for outfalls, the real driver is the load that is entering the system. By applying a watershed-based TMDL approach to address urban runoff and other sources of pollution, as recommended by the National Research Council (NRC 2008), TMDLs can aide in the implementation of Water Quality Improvement Projects by determining the critical conditions and major sources of contaminants (US EPA 2009) which can be used to identify the best return on investment in improving environmental quality in the Inlets.

Table 9. Results of sensitivity analysis of selected parameters for OF 19.

					Trajectory					
Base Simulation			%Change		meters	feet				
Background Conc	0.818	ppb Cu Dissolved		CMC Found	39.53	129.70				
Steady Velocity (UA)	0.289	cm/s		CCC Found	63.28	207.62				
Wind Speed (UW)	0	m/s								
Scenaro 1							Relative Change from Base			
Background Conc	**1.500**	ppb Cu Dissolved	183.4%	CMC Found	45.88	150.52	increased by	20.82	ft	16.1%
Steady Velocity (UA)	0.289	cm/s		CCC Found	73.81	242.16	increased by	34.54	ft	16.6%
Wind Speed (UW)	0	m/s								
Scenaro 2										
Background Conc	0.818	ppb Cu Dissolved		CMC Found	39.53	129.70	no change	0.00	ft	0.0%
Steady Velocity (UA)	0.289	cm/s		CCC Found	63.28	207.62	no change	0.00	ft	0.0%
Wind Speed (UW)	**10**	m/s	NA							
Scenaro 3										
Background Conc	0.818	ppb Cu Dissolved		CMC Found	1.17	3.83	decreased by	-125.87	ft	-97.0%
Steady Velocity (UA)	**10.000**	cm/s	3460%	CCC Found	1.59	5.23	decreased by	-202.39	ft	-97.5%
Wind Speed (UW)	0	m/s								
Scenaro 4										
Background Conc	**1.500**	ppb Cu Dissolved	183%	CMC Found	1.20	3.92	decreased by	-125.77	ft	-97.0%
Steady Velocity (UA)	**10.000**	cm/s	3460%	CCC Found	1.97	6.48	decreased by	-201.15	ft	-96.9%
Wind Speed (UW)	0	m/s								

5. SUMMARY AND CONCLUSIONS

The CORMIX modeling framework was used to simulate theoretical steady-state discharges from Shipyard using the existing data on the discharge geometry, effluents, ambient conditions, and discharge characteristics to estimate mixing zone dimensions needed to meet water quality standards. The CORMIX model was used to calculate mixing zones for Cu discharges from industrial outfalls for the dry docks, storm drains from stormwater basins, and temperature discharges from the steam plant (Table 6).

Based on the assumptions used in the model analysis, the mixing zones for copper discharges from industrial were calculated as follows:

- Mixing zones for OF 18A were 49.3 m for CMC (acute) and 508.2 m for CCC (chronic) exposures;
- Mixing zones for OF 18B were 18.4 m for CMC and 32.6 m for CCC; and
- Mixing zones for OF 19 were 39.5 m for CMC and 63.3 for CCC.

Because the dry dock discharges are intermittent, only discharging 6 to 12 hr during every 24 hr period, the permit limit derived from these mixing zones should be adjusted upward by a factor of two to four as allowed by the State of Washington guidance (Bailey 2008). Additionally, the permit limits derived from these mixing zones should take into account any other site-specific factors that may be incorporated into the permit (Washington State 2006), such as Water Effect Ratios and site-specific dissolved to total translators. The results from the dye study of the dry dock outfalls showed that the dye plumes reached background concentrations (i.e. concentrations that would be much lower than the CMC or CCC) within 100 m of where the plumes surfaced which indicates that the CORMIX simulations are probably more conservative than the actual discharge conditions.

The CORMIX model of the steam plant thermal discharge predicted that a mixing zone of 0.6 m would be required to meet water quality standards for temperature.

The CORMIX model was also used to simulate three stormwater basins representing large, medium, and small stormwater discharges to bracket the range of stormwater plumes expected from the Shipyard. The effluent concentrations of the stormwater were set to the 90th percentile concentration measured in the stormwater basins to calculate the mixing needed to meet water quality standards. The results showed that if the stormwater discharged at depth of 6 ft below the surface mixing zones of 1.5 m, 287.1 m, and 34.3 m would be needed to meet the CMC, for the large, medium, and small stormwater basins, respectively. If the stormwater discharges occurred at a depth of 1 ft, considerably larger mixing zones would be required.

The accuracy of the CORMIX results obtained for the storm drain discharges are highly questionable, because the CORMIX model is not designed to model surface discharges with low momentum like stormwater. Furthermore, the hypothetical CORMIX simulations of industrial and stormwater outfalls from the Shipyard neglect the effects of tidal action, intermittent discharges, the complex geometry present near the outfall discharges, over-lapping discharge plumes, and recirculation (estuarine) flow. In addition, other sources of Cu within the Inlets were not included in the discharge scenarios simulated. Therefore, the CORMIX results reported in this document are provided to inform the permit development process and do not represent actual conditions present in the receiving waters of the Inlets

Probably, the biggest source of uncertainty is the fact that the CORMIX analyses did not include any other sources of Cu in the Inlet. Because there are such a wide range of spatial and temporally varying inputs of Cu from Navy as well as civilian sources (Table 8), the mixing analysis really needs to address the cumulative impacts of the many sources of Cu in the Inlets. This is a prime example of the need for a TMDL approach to determine the amount of Cu that can be discharged into the Inlets without causing the Inlets to exceed water quality standards. While the NPDES permitting process is primarily focused on setting concentration limits for industrial outfalls, the real driver is the load that is entering the system. By applying a watershed-based TMDL approach to address urban runoff and other sources of pollution, as recommended by the National Research Council (NRC 2008), the determination of critical conditions and major sources of pollution can be used to implement Water Quality Improvement Projects (US EPA 2009) that will achieve the best return on investment in improving environmental quality in the Inlets.

Currently, the Navy is completing a model verification study of copper loading from all sources in Sinclair and Dyes Inlet, using CH3D-CU, a version of CH3D containing a module to simulate copper speciation and running on high resolution grid in the vicinity of the Shipyard (Figure 17). Upon successful verification of the copper model (CH3D-CU), the copper model could be used to simulate specific discharge scenarios to better inform the NPDES permitting process.

6. REFERENCES

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7. APPENDICES

7.1 STATISTICAL ANALYSIS OF AMBIENT COPPER DATA

BB_NPDESPermitLimitsCalcsModel9.xls

7.2 CORMIX MODEL FILES

BB_CORMIXlFiles.zip

CORMIX Metadat file

7.3 LINKS TO RAW DATA SETS

<under development>